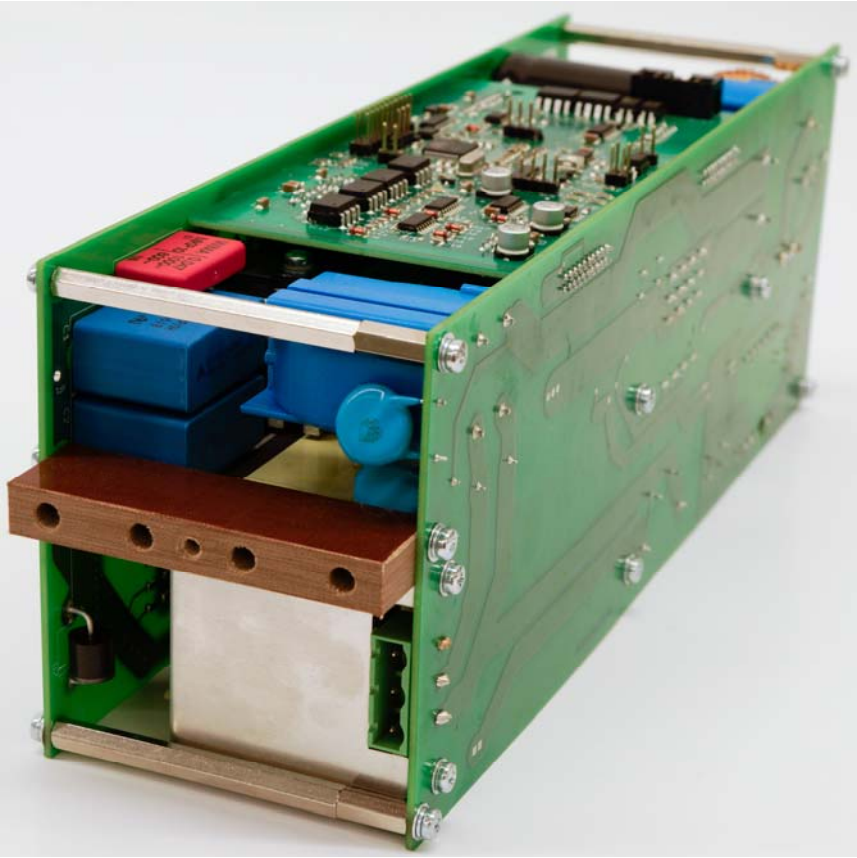
FLEXIVA

User Manual



PM3AC10-1x

Bidirectional 2.3 kW DC/AC Inverter Module

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Preface

The present Technical Documentation is to inform of the correct operation and handling of the DC/AC module module PM3AC10 (DC/AC module). The modules serve to convert a direct voltage (e.g. DC link of the converter) into an alternating voltage of 230V / 50Hz.

The operating manual is to be preserved.

It is prohibited to copy or duplicate texts, plans, and tables or to make them accessible to any third parties without our express consent.

We draw your attention to the fact that the Technical Documentation shall not be part of an existing earlier agreement or promise or part of a legal relationship.

All and any obligations result from the purchase contract that also solely contains the warranty determination. The contractual provisions shall not be affected by the Technical Documentation.

The documentations of the suppliers used shall apply along with the present documentation of the manufacturer.

In addition to the operating manual, all universally valid legal and other obligatory regulations concerning the prevention of accidents and the environmental protection are to be complied with and to be applied.

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1 Introduction

In order to guarantee the safety of the operator and to avoid possible damages at the module, you have to ensure by all means that the present user's manual has been read completely before starting to use the module and/or the plant connected with it.

The present user's manual is to help you to get to know the DC/AC module better and to enable you to use it according to the intended working possibilities.

Prior to the commissioning, the operating staff has to familiarize itself with all sub-units and their functions. Particular attention is to be paid to the paragraph safety.

The present user's manual contains important information on the correct and economical application of the DC/AC module. The compliance with these instructions contributes to the fact that dangers are avoided, costs owing to repairs and breakdown times are reduced, and the service life of the module is prolonged.

A symbol is provided at the text margin in the chapters if required that refers to the function of the respective text section and is of importance with regard to the operation or the maintenance and/or indicates important descriptions or notes:

Danger

All sections in the manual containing information on possible dangers are marked with the marginal symbol.
The non-observance can lead to serious injuries! The instructions are to be strictly complied with.

Attention

All sections with this symbol provide instructions how to avoid damages at the unit.

Advice

Sections with this symbol give important details for an efficient work.

The work steps that are described in logical order at the side of this symbol inform the operator of the most ergonomic proceeding of the operation.

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2 Identification

2.1 Product Trademark and Type Designation

ZEMIS® PM3AC10

2.2 Product Version / Version of Software / Editing State

Product Version:	PM3AC10-1x
Firmware:	2.13
State:	2015

3 Product Description

3.1 General Information / Utilization as Directed

The DC/AC module serves to generate an alternating voltage from a direct voltage (e.g. DC link voltage of 375V). It is intended to be used in connection with the DC/DC converter modules of the type PM3Kxxx. Both, island operation and mains operation, are possible with the DC/AC module i.e. it is possible to operate a single electric consumer as well as to feed into the power supply system.

Attention

The DC/AC module does not offer any galvanic isolation of the DC link and the output! In case of the interconnection with other modules without galvanic isolation, this can lead to the damaging of the DC/AC module.

Terms and abbreviations

DC link: Prefix: _zk	DC link (DC side) This is the designation for the side of the module by means of which the coupling with DC/CC modules or the link of any other DC component can be carried out.
Output: Prefix: _a	Output side (AC side, component side) On that side of the module, the mains as well as the electric consumers can be connected (depends on the selected operation mode).
Mains operation: (on-grid)	In the mains operation, the DC/AC module is connected to the electric network and works as a current source. In this case, both feeding into the mains, as well as power drain from the mains is possible.
Island operation: (off-grid)	In the island operation, electric consumers can be directly connected to the DC/AC module. It works as a voltage source.

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3.2 Technical Information and Data

General characteristics

Grid-connected operation:	yes
Island operation:	yes
Bi-directional power flow:	yes
Parallel connection:	yes
Galvanic isolation: (ZK vs. AC)	no
Generation of reactive power:	yes

Performance data

Rated power:	2.3 kW
AC current range:	0…10A_{RMS}
AC voltage range:	0…250V_{RMS} (output voltage < DC link voltage)
Rated frequency:	50Hz, 60Hz
Frequency range in island operation:	40Hz-70Hz
Overload capability in island operation:	16A_{RMS} for max. 30s
DC link voltage:	100…395V DC
Control interface:	USART (CMOS 5V); galvanic isolated
Auxiliary power supply:	12…30V DC, 10W; galvanic isolated
Own consumption:	standby: max. 5W during operation: max. 10W
Cooling:	forced air cooling (temperature-controlled fan)
Efficiency:	> 90%
Accuracy:	better than ± 3 % of full scale

Ambient conditions

Ambient temperature range :	-20..50°C (during operation)
Degree of protection:	IP 00
Maximum humidity:	up to 90% (non-condensing)
Pollutants:	The environment must not contain larger quantities of dust, in particular no metal or graphite dust.

Housing

Design:	open frame
Dimensions:	270 mm x 85 mm x 105 mm
Weight:	approx. 2.9 kg

Scope of delivery

- DC/AC module PM3AC10 (pre-parameterized)
- Data disk (CD)
- Software for visualization and parameterization (on CD)
- User manual (on CD)

Optional

- Device system for max. 4 modules (variants on request)
- Pre-parameterization according to the planned application

3.3 Power Connectors

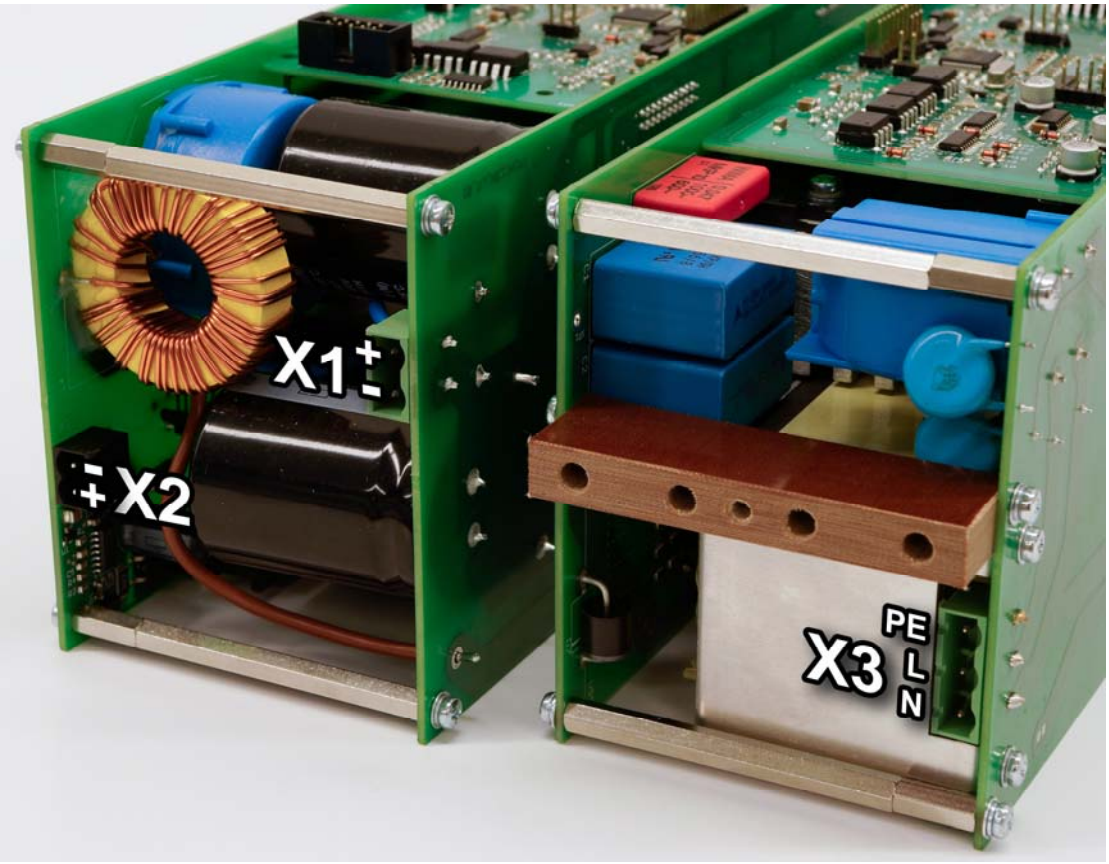

Fig. 1: Power connectors

X1: DC link connection (DC side, DC link)

- Plug with clamp max. 2.5mm²

X2: Connection for auxiliary supply

- Plug with clamp max. 1.5mm²
- 12…30V DC

X3: Output connection (AC side, component side)

- Plug with clamp max. 2.5mm²
- N, L, PE

3.4 Signal Connectors

Fig. 2: Signal connectors

SV1: Communication interface

The communication with the module is executed by means of an optically isolated serial interface: To trigger the optocouplers, a supply voltage of 5V (approx. 30mA) is to be provided. To permit to address several modules in a simple way, the signals RXD and TXD can be switched-in by means of the SELECT signal. When SELECT is low, TXD becomes a high-resistance value and RXD does not receive any signals. When several modules are used, the RXD and TXD lines can be connected in parallel this way and the currently addressed module can be selected by means of SELECT.

Data rate: 115200 bps,

Format: 8 bit + 1 stop bit

The signals OC_OK and OC_EN are provided for an additional safety feature: OC_OK gets low, when the DC link voltage has exceeded the upper limit value. Consequently, a module can inform all the others when this case has occurred by AND-combining all OC - OK signals and supplying them to OC - EN. This way, it is possible to prevent major damages when the voltage-measuring amplifier of the DC link of a module breaks down.

Pin	Abbre-viation	Explanation
1	GND	ground
2	VCC	+5 V
3	OC_OK	H: no overvoltage of the DC link
4	NC	not used
5	NC	not used
6	SELECT	H: serial interface activated L: serial interface deactivated
7	OC_EN	H: module enabled
8	RXD	input of data
9	NC	not used
10	TXD	output of data

Tab. 1: Pin assignment SV3

SV2, SV3, SV4, SV5, TST: Service interfaces

The service interfaces are not needed for the operation and are not to be used.

JP1, JP2, JP4: SYNC-IN / SYNC_OUT: Synchronizing inputs/outputs

These connections serve for the synchronization of several modules in the island operation in case of parallel connection or multiphase operation. If the synchronization has been successful, the signal at SYNC_OUT is in phase to the signal at SYNC_IN. A parameterized phase displacement has only effects on the power output, not on the signal at SYNC_OUT.

When using several DC/AC modules in a module carrier of Flexiva (e.g. WG5K020) master and slaves are already factory connected and labeled accordingly.

Fig. 3: Labeling of master and slaves in the module carrier

3.5 Basic Structure and Method of Functioning of the DC/AC Module

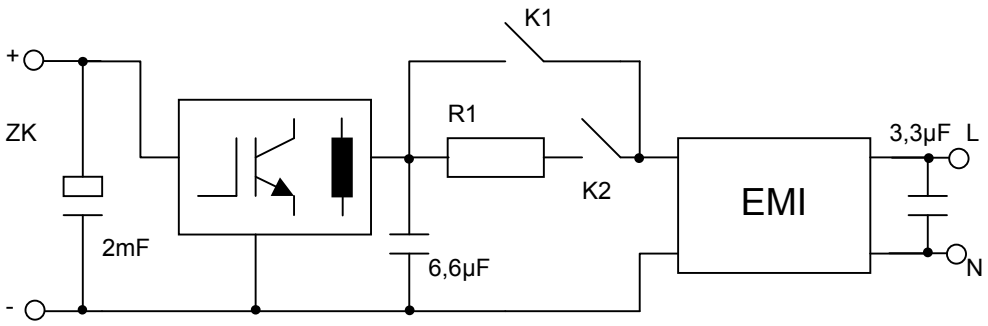

Fig. 4: Structure of the DC/AC module

The negative pole of the DC link is gallvanically connected with the N-connection of the AC side. The L-connection of the AC side can be maximally the DC link voltage +UZK and minimally the DC link voltage -UZK.

In the switched-off condition, the contacts K1 and K2 are open. During the switching-on, K2 is closed first and charges the possibly empty DC link by means of the resistor R1. These are two PTC resistors of the type EPCOS B59754D0120A70, each with a value of 150Ohm in cold condition, that are switched in parallel. If the DC link cannot be charged because of an error (short circuit, too high capacity), these resistors get high-resistance resistors and limit the current to an undangerous value.

After the successful charging of the DC link, the contact K1 is closed and the power stage is switched-in.

3.6 Safety Information

The DC/AC modules were developed according to recognized rules of technology and submitted to a safety test before the delivery.

In case of wrong operations or unauthorized use, there are still dangers for persons and the DC/AC module.

All persons who erect, operate, or maintain the system must:

1. read and exactly follow the present operating manual,
2. be trained and instructed for their job.

Test voltage between DC link side and communication interface: 6kVp

Test voltage between DC link side and auxiliary supply: 6kVp

3.6.1 Safety Measures for the Installation

In order to guarantee a troublefree operation and to maintain the service life of the electronic components, any accumulation of heat, especially at the fronts of the module (fan and opposite side) is to be avoided. The place of installation is to be selected so that the module is sufficiently ventilated during the operation.

Attention

The heat sinks are connected with potentials i.e. it is prohibited to touch them!

3.6.2 Remaining Dangers and Risks

The described product is in keeping with the latest technological development and meets the recognized safety provisions. Nevertheless, dangers and risks may arise.

The remaining dangers and risks occurring in connection with the operation of the system result from:

- the utilization of electric / electronic components /sources, acceptors, memories) of third-party suppliers,
- the electricity itself.

For all components built-in, the provisions and safety instructions with regard to the operation and the place of erection and/or installation applying to each of them are to be observed and complied with.

3.6.3 Qualification of the Operating Staff

Only such persons are authorized to commission and connect the module who have an electro-technical special training and who are able to execute the required line connections expertly.

Basic knowledge of the work on PCs and with the current WINDOWS operating system is required to use the software supplied along with the modules. Details about this are contained in the enclosed extensive program description.

4 Preparation of the Product for the Use

4.1 Transport of the Module

For the transport of the module, attention has to be to the fact that it is not exposed to any vibrations, heavy shocks as well as jolts and impacts since sensitive components might be damaged by that.

4.2 Packaging of the Module

Basically, packaging is to be used for the transport and/or shipment of the module that meets the requirements of the destination and the system and is environmentally acceptable.

Since the module itself has a degree of protection IP00, a transport packing is to be selected that prevents the penetrating of water, dirt, and dust. The inserting of conventional desiccating means in the packaging is recommended.

4.3 Storing of the Module

Durable storing: closed rooms, dry, room temperature

4.4 Commissioning of the Module

Prior to the commissioning, the following conditions are to be assured and to be checked:

- The expert installation and rating of all necessary electrical connection lines as well as the correct connection of all components to the module.
- The knowledge of the information and instructions given in the present user's manual.

4.4.1 Connection of the DC Link (DC link side)

- The cross section of the wires has to be selected according to the expected current → at least 1.5mm² are recommended.
- Take into account the polarity.

4.4.2 Connection of the Output (AC side)

- The cross section of the wires has to be selected according to the expected current → at least 1.5mm² are recommended.

4.4.3 Connection of the Auxiliary Supply

- 12…30V DC, 1.5mm²
- Observe the polarity!

4.4.4 Connection of the Communication

- 5V DC operating voltage required.
- CMOS level → level converter to RS232 level required.
- OC_EN has to be set to +5V for operation.

4.4.5 Putting the Module into Operation

1. Read the present documentation
2. Connect the auxiliary supply
3. Parameterize
4. Switch it on

5 Operation

5.1 Method of Functioning

The DC/AC module is suited for the supply of directly connected electrical loads (island operation). In this case, the output voltage (AC side) is kept at a constant level. The operation at the mains (mains operation) is possible, too. Here, the output current (AC side) is kept at a constant level. In this mode of operation, a bidirectional working is possible i.e. power can also be drawn from the mains and supplied to the DC link. For the changeover between the two, the parameter for the mode of operation of the module (mod_opmode) has to be changed.

The output variables current and voltage are sinusoidal. For the control of the DC link voltage, a PIT1 regulator is available that is realized by means of software. Its output is connected with the desired values for the output variable and, thus, offers various possibilities for the voltage control of the DC link.

5.1.1 Modes of Operation

The DC/AC module offers various modes of operation. In principle, you can distinguish between 2 groups of modes of operation: modes of operation in island operation and modes of operation in mains operation. The switchover between island and mains operation is done by means of bit 1 of the parameter mod_opmode. The following tables give a survey over the possible modes of operation in the two groups of modes of operation and the corresponding bit combinations of the parameter mod_opmode.

If bit 1 of mod_opmode is 0, it works in the island operation. If bit 0 is 0, a PI regulator is used to control the output voltage, if bit 0 is 1, a PI regulator with resonant integrator is used. In both modes of operation, there exists a regulator for the DC link voltage limiting the same downwards.

If bit 1 is 1, the DC/AC module can be operated at the mains. Bit 0 has no function yet here and should be 0. The DC/AC module works in this case as current source. There are two DC link voltage regulators available. One for a (selectable) lower voltage limit, the other for a (selectable) upper voltage limit.

Assistance during the fixing of the right mode of operation is offered by the corresponding dialogue in the software „ModuleConfigSuite“ (See 7.4.10).

Parameter: mod_opmode			
Bit	**Dec**	**Meaning in island operation**	**Meaning in mains operation**
0	**1**	Type of the output voltage regulator	not used
1	**2**	Island operation / Mains operation	Island operation / Mains operation
2	**4**	not used	not used
3	**8**	DC link voltage mode	DC link voltage mode
4	**16**	not used	Reactive current mode
5	**32**	Synchronisation	not used
6	**64**	Mehrphasenbetrieb / Parallelbetrieb	not used
7	**128**	not used	not used

Tab. 2: mod_opmode

Parameter: mod_opmode										
Bit								**Dec**	**Hex**	**Meaning**
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**			
0	x	x	0	x	0	0	0	0	0x00	PI regulator
0	x	x	0	x	0	0	1	1	0x01	Resonant PI regulator
0	x	x	0	0	0	0	x	0	0x00	Normal DC link voltage range 350..400V
0	x	x	0	1	0	0	x	8	0x08	Full DC link voltage range 0..400V
0	0	1	0	x	0	0	x	32	0x20	Parallel mode
0	1	1	0	x	0	0	x	96	0x60	Multi-phase mode

Tab. 3: Options in island operation

Parameter: mod_opmode										
Bit								**Dec**	**Hex**	**Meaning**
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**			
0	0	0	x	x	0	1	0	2	0x02	Mains operation
0	0	0	x	0	0	1	x	0	0x00	Normal DC link voltage range 350..400V
0	0	0	x	1	0	1	x	8	0x08	Full DC link voltage range 0..400V
0	0	0	0	x	0	1	x	2	0x02	Reactive power via phase angle setting
0	0	0	1	x	0	1	x	18	0x12	Reactive power via reactive current setting

Tab. 4: Options in mains operation

5.1.2 Monitoring Functions / Shutdowns on Faults

The module is equipped with numerous monitoring functions that are explained in the following. If there is a fault shutdown executed, the corresponding bits (see table below) are set in the variable mod_state. Before the module can be restarted, the faults occurred have to be acknoweldged by setting the variable err_quit to 1.

Overcurrent at the output (island operation, mains operation)
→ "Overcurrent at the output"
Is indicated when the hardware overcurrent shutdown was activated.

Overvoltage at the DC link (island operation, mains operation)
→ "U_ZK too high“

If the DC link voltage exceeds 400V, there is a fault shutdown carried out.
In the full range DC link voltage mode, there is an additional shutdown carried out if the DC link voltage exceeds the value 1,5*zk_usollvh.

Overtemperature (island operation, mains operation)
→ "Overtemperature“

For the overtemperature shutdown, the temperature of the heat sink element is monitored. At a temperature of more than 90 °C at the heat sink element, the shutdown is carried out with an error message.

Undervoltage at the DC link (island operation, mains operation)

→ "U_ZK too low“

In the normal range DC link voltage mode, there is a shutdown carried out because of DC link undervoltage at 351V.

In the full range DC link voltage mode, it is distinguished between mains operation and island operation. In both cases, i.e. in mains operation as well as island operation, a shutdown is carried out if the DC link voltage zk_uist is smaller than 95% of the bottom desired value zk_usollv.

In the mains operation, a fault shutdown is carried out if zk_uist<a_ueff*1.4 is, i.e. if the peak voltage at the output (AC side) is more than 99% of the DC link voltage.

In the island operation, a fault shutdown is carried out if the DC link voltage is smaller than the peak value of the desired value of the output voltage (AC side).

Overload (island operation)
→ "Overload“

Is more power demanded on the AC side than is available via the DC link, the DC link voltage regulator reduces the output voltage. If as a result the output voltage is smaller than the desired value for more than 10s, a fault shutdown is carried out.

If the output current exceeds a value of 10.5A for more than 30s, a fault shutdown is carried out.

Frequency deviation (island operation, mains operation)

→ "Frequency deviation“

In the mains operation, the frequency of the DC/AC module is constantly adjusted according to the mains frequency by means of PLL. If a deviation of the parameterized desired frequency from the mains frequency is determined that is more than 0.5Hz, a fault shutdown is carried out.

In the island operation, the frequency is also monitored, namely in the parallel operation and in the multiphase operation. Here, a fault shutdown is carried out when the frequency differs more than 4,5Hz from the set value.

Synchronization error (island operation, mains operation)

→ "Synchronization error“

When the synchronization failed in the mains operation or in the parallel operation / multiphase operation (synchronized island operation), a fault shutdown is carried out.

In the island operation, this fault is also indicated in the following cases:

- There is no valid synchronization signal available.
  (Frequency not between 37..74Hz).
- In the parallel operation, before switching-on, the slave module compares its own phase with the phase relation of the voltage of the master module. If these do not correspond, a fault shutdown is carried out.

Parameter: mod_state											
Bit								Dec	Hex	Meaning in mains operation	Meaning in island operation
7	6	5	4	3	2	1	0				
0	0	0	0	0	0	0	0	0	0x00	no error	no error
0	0	0	0	0	0	0	1	1	0x01	Overcurrent at the output	Overcurrent at the output
0	0	0	0	0	0	1	0	2	0x02	U_ZK too high	U_ZK too high
0	0	0	0	0	1	0	0	4	0x04	Overtemperature	Overtemperature
0	0	0	0	1	0	0	0	8	0x08	U_ZK too low	U_ZK too low
0	0	0	1	0	0	0	0	16	0x10	Frequency deviation	Frequency deviation / Overload
0	0	1	0	0	0	0	0	32	0x20	Synchronization error	Synchronization error
0	1	0	0	0	0	0	0	64	0x40	Over-/under- voltage at the output	Output not voltage-free
1	0	0	0	0	0	0	0	128	0x80	Hardware error	Hardware error

Tab. 5: Error codes

Monitoring of the output voltage (island operation, mains operation)

Island operation: → "Output not voltage-free“

Mains operation: → "Overvoltage/undervoltage at the output“

Prior to the switching-on, the existence of a voltage at the output is checked. If there is no voltage available in the mains operation or if there is already a voltage in the island operation, a fault shutdown is carried out.

In the mains operation, the mains voltage is monitored, too. If it differs by +/- 15% from the desired value, a fault shutdown is carried out.

Hardware error (island operation, mains operation)
→ "Hardware error“
A hardware error either occurs when there has a problem in the power supply of the module occurred or when the overvoltage shutdown of the DC link of another module was triggert and the signal OC_EN is low at the communication interface.

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5.2 Parameterization

The module can only be parameterized by means of the serial interface. It is, however, more convenient to do this by means of the parameterizing software "ModuleConfigSuite“.

R readable

W writable (parameterizable)

E stored in the EEPROM (EEP)

B can be changed in switched-on state (mod_on=1)

5.2.1 Parameters and Measured Values of the Output Side (AC side)

parameter	**a_fsoll**	
description	frequency, desired value	
explanation	scaling: 40Hz…70Hz -> 4000…7000	
command	wf	**RW**

parameter	**a_fsoll_f**	
description	frequency, desired initial value in eeprom	
explanation	scaling: 40Hz…70Hz -> 4000…7000	
command	wg	**RW E**

parameter	**a_fist**	
description	frequency, actual value	
explanation	scaling: 40Hz…70Hz -> 4000…7000	
command	wh	**R**

parameter	**a_phase**	
description	phase angle of the current in mains op. (limited to ±40°) power into the mains: +→capac. -→induct. power from the mains: +→induct. -→capac. phase angle of the voltage in multiph. op.	
explanation	scaling: -180°…180° -> -1800…1800	
command	wp	**RW**

parameter	**a_phase_f**	
description	phase angle of the current in mains op. phase angle of the voltage in multiph. op initial value in eeprom	
explanation	scaling: -180°…180° -> -1800…1800	
command	wq	**RW E**

parameter	**a_isoll**	
description	current, desired value, mains operation + → power into the grid - → power from the grid	
explanation	scaling: -10A…10A -> -1000…1000	
command	wi	**RW B**

parameter	**a_isoll_f**	
description	current, desired value, mains operation, initial value in eeprom	
explanation	scaling: -10A…10A -> -1000…1000	
command	wj	**RW E**

parameter	**a_iblind_soll**	
description	reactive current, desired value, mains op., + → capacitive reactive current - → inductive reactive current	
explanation	scaling: -10A…10A -> -1000…1000	
command	wk	**RW B**

parameter	**a_iblind_soll_f**	
description	reactive current, desired value, mains op., initial value in eeprom	
explanation	scaling: -10A…10A -> -1000…1000	
command	wl	**RW E**

parameter	**a_usoll**	
description	voltage, desired value	
explanation	scaling: 0…260V -> 0…2600	
command	wu	**RW B**

parameter	**a_usoll_f**	
description	voltage, desired value, initial value in eeprom	
explanation	scaling: 0…260V -> 0…2600	
command	wv	**RW E**

parameter	**a_kri**	
description	internal resistance, desired value (parallel operation only)	
explanation	scaling: 0…26.1 Ohm -> 0…255	
command	wz	**RW E**

parameter	**a_ueff**	
description	r.m.s. value of the output voltage (between module and its internal relay)	
explanation	scaling: 0…400V -> 0…4000	
command	vu	**R**

parameter	**n_ueff**	
description	r.m.s. value of the mains voltage (between the internal relay and the mains)	
explanation	scaling: 0…400V -> 0…4000	
command	vw	**R**

parameter	**a_ieff**	
description	r.m.s. value of the output current	
explanation	scaling: 0…20A -> 0…2000	
command	vi	**R**

parameter	**a_p**	
description	power, actual value + → power is delivered to the AC side - → power is taken from the AC side	
explanation	scaling: -8000W…8000W -> -8000…8000	
command	vp	**R**

parameter	**a_udc**	
description	voltage, DC component	
explanation	scaling: -1.524V…1.572V -> -1524…1527	
command	vd	**R**

parameter	**a_iampl**	
description	current, actual amplitude value (mains operation)	
explanation	scaling: -10Aeff…10Aeff -> -1000…1000	
command	vj	**R**

parameter	**a_uampl**	
description	voltage, actual amplitude value (island operation)	
explanation	scaling: 0…260V -> 0…2600	
command	vv	**R**

5.2.2 Parameters and Measured Values for the DC Link Side

Normal voltage range

parameter	**zk_usoll**	
description	voltage, lower regulator, desired value	
explanation	scaling: 350V…400V -> 3500…4000	
command	zu	**RW B**

parameter	**zk_usoll_f**	
description	voltage, lower regulator, desired initial value in eeprom	
explanation	scaling: 350V…400V -> 3500…4000	
command	zv	**RW E**

parameter	**zk_usollh**	
description	voltage, upper regulator, desired value	
explanation	scaling: 350V…400V -> 3500…4000	
command	zs	**RW B**

parameter	**zk_usollh_f**	
description	voltage, upper regulator, desired initial value in eeprom	
explanation	scaling: 350V…400V -> 3500…4000	
command	zt	**RW E**

parameter	**zk_uist**	
description	voltage, actual value resolution 0V…350V: 0.4 V resolution 350V…400V: app. 0.07V	
explanation	scaling: 0V…400V -> 0…4000	
command	za	**R**

Full voltage range

parameter	**zk_usollv**	
description	voltage, lower regulator,desired value	
explanation	scaling: 0V…400V -> 0…4000	
command	zq	**RW B**

parameter	**zk_usollv_f**	
description	voltage, lower regulator, desired initial value in eeprom	
explanation	scaling: 0V…400V -> 0…4000	
command	zr	**RW E**

parameter	**zk_usollvh**	
description	voltage, upper regulator,desired value	
explanation	scaling: 0V…400V -> 0…4000	
command	zo	**RW B**

parameter	**zk_usollvh_f**	
description	voltage, upper regulator, desired initial value in eeprom	
explanation	scaling: 0V…400V -> 0…4000	
command	zp	**RW E**

parameter	**zk_uistv**	
description	voltage, actual value resolution: 0…400V: 0.4V	
explanation	scaling: 0V…400V -> 0…4000	
command	zb	**R**

Normal / Full voltage range

parameter	**zk_umax_g**	
description	voltage, upper limit	
explanation	scaling: 0V…400V -> 0…4000 not used	
command	zm	**RW E**

parameter	**zk_umin_g**	
description	voltage, lower limit	
explanation	scaling: 0V…400V -> 0…4000 not used	
command	zn	**RW E**

parameter	**zk_ki**	
description	regulator, I-component	
explanation	parameter range: 0…1023 transfer function: G=VI/p VI: 0…602s-1 VI=zk_ki*4825Hz/8192	
command	yi	**RW E**

parameter	**zk_kp**	
description	regulator, P-component	
explanation	parameter range: 0…1024 gain: 0…4	
command	yp	**RW E**

parameter	**zk_kt**	
description	regulator, time constant	
explanation	parameter range: 0…1024 transfer function: G=1(1+pT) T: 212ms…0.21ms T=1024/(zk_kt*4825Hz)	
command	yt	**RW E**

parameter	**zk_uf**	
description	voltage window for the gain increase	
explanation	parameter range: 0…150 voltage range: 0…±10V (normal voltage range), 0…±15V (full voltage range)	
command	yf	**RW E**

parameter	**zk_kv**	
description	gain increase outside the voltage window	
explanation	parameter range: 0…255 gain: 0…16	
command	yv	**RW E**

parameter	**zk_fkkp**	
description	falling characteristic, gain „internal resistance“	
explanation	parameter range: 0…255 gain in mains operation: 0…13V/10Aeff (normal voltage range) 0…20V/10Aeff (full voltage range) gain in island operation: 0…13.5V/2.3kW (normal voltage range) 0…20.5V/2.3kW (full voltage range)	
command	yk	**RW E**

parameter	**zk_fkkt**	
description	falling characteristic, filter time const. „internal resistance“	
explanation	parameter range: 0…1024 transfer funktion: G=1(1+pT) T: 212ms…0.21ms T=1024/(zk_kt*4825Hz)	
command	yz	**RW E**

5.2.3 Information

parameter	**mod_state**	
description	module, state	
explanation	see Tab. 5	
command	Is	**R**

parameter	**mod_opmode**	
description	module, operating mode	
explanation	see Tab. 3	
command	im	**RW E**

parameter	**-**	
description	module, type	
explanation	module type: AC2	
command	it	**R**

parameter	**-**	
description	module, firmware	
explanation	software version of the firmware	
command	if	**R**

parameter	**-**	
description	module, serial number	
explanation	serial number of the manufacturer	
command	in	**R**

parameter	**-**	
description	module, date of manufacture	
explanation	date of manufacture	
command	id	**R**

parameter	**t_kk**	
description	temperature, heat sink	
explanation	scaling: –112…160°C -> -1120…1600	
command	tk	**R**

5.2.4 Commands

parameter	**mod_on**	
description	module on / off	
explanation	1: on 0: off	
command	ce	**RW B**

parameter	**err_quit**	
description	acknowledge an error	
explanation	1: acknowledging the error	
command	cq	**RW B**

parameter	**com_mode**	
description	communication mode	
explanation	0: ASCII short 1: ASCII long	
command	cc	**R B**

5.2.5 Oscilloscope

For the setting of the regulator parameters and for the observing in the operation, an oscilloscope functionality is integrated into the software. By means of it, output voltage, DC link voltage and output current can be recorded. 13 channels with 512 values each with a scope of values of 16bit are recorded. The possible scanning frequency is in the range from 9.654 kHz and 37.9 Hz.
The channel where triggering is done can be selected independently of the recorded channel.
The values are not scaled. i.e. they are internal operands.

Ch		Description	Scaled range	Real range
0	zk_uist	DC link voltage normal voltage range	5280 6040	350V 400V
1	zk_uist_v	DC link voltage full voltage range	0 +4000	0V +400V
2	i_aistb	Output current, actual value, calculated from l1_iist and l2_iist	-2970 +2970	-20A +20A
3	n_uist	Mains voltage, actual value	-1952 +1952	-400V +400V
4	a_uist	Output voltage, actual value	-2014 2014	-400V +400V
5	l1_iist	Current inductor 1	-2120 1976	-19.9A +18.5A
6	l2_iist	Current inductor 2	-2120 1952	-19.9A +18.5A
7	usoll	Desired voltage value (in island operation only)	-2014 2014	-400V 400V
8	isoll	Desired current value	-2120 2120	-19.9A +19.9A
9	il1_soll_glob	Desired current value of inductor 1 (identical to inductor 2)	-2120 1976	-19.9A +18.5A
10	sin_ampl	Amplitude of the desired value: voltage in island operation current in mains operation	-790 790 0 906	-10A 10A 0V 260V
11	a_udc	DC voltage component at the output	-1952 1952	-1.5V 1.5V
12	l1_soll_glob	Desired voltage value for the Modulator	-2014 2014	-400V 400V

parameter	**osz_ch**	
description	channel	
explanation	parameter range: 0…12	
command	ok	**RW B**

parameter	**osz_ft**	
description	frequency devider	
explanation	clock: 9.654kHz/osz_ft 0 corresponds to 9.654kHz	
command	of	**RW B**

parameter	**osz_tr**	
description	trigger value	
explanation	trigger value for all channels	
command	ot	**RW B**

parameter	**osz_tch**	
description	trigger channel	
explanation	parameter range: 0…12	
command	oc	**RW B**

parameter	**osz_m**	
description	storage mode	
explanation	see Tab. 6	
command	om	**RW B**

Parameter: osz_m										
Bit								**Dec**	**Hex**	**Meaning**
7	**6**	**5**	**4**	**3**	**2**	**1**	**0**			
x	x	x	x	x	x	x	0	0	0x00	trigger at: value > trigger value
x	x	x	x	x	x	x	1	1	0x01	trigger at: value < trigger value
x	x	x	0	0	x	x	x	0	0x00	trigger position: 0 %
x	x	x	0	1	x	x	x	8	0x08	trigger position: 25%
x	x	x	1	0	x	x	x	16	0x10	trigger position: 50%
x	x	x	1	1	x	x	x	24	0x18	trigger position: 75%

Tab. 6: Modes of operation of oscilloscope

parameter	**osz_on**	
description	oscilloscope on / off	
explanation	start/stop; status	
command	oe	**RW B**

parameter	**-**	
description	read data, only the channel osz_ch	
explanation	reads the 512 values (ASCII, separated by 0x0D 0x0A)	
command	or	**R**

parameter	**-**	
description	read data, all channels	
explanation	reads all the values of all channels (ASCII, separated by blank, end of line: 0x0D)	
command	os	**R**

Parameter: osz_on										
Bit								Dec	Hex	Meaning
7	6	5	4	3	2	1	0			
0	0	0	0	0	0	0	0	0	0x00	not running
x	x	x	x	x	x	x	1	1	0x01	runs, waits for trigger
x	x	x	x	x	x	1	x	2	0x02	runs, triggert
x	x	x	x	x	1	x	x	4	0x04	runs, forerun before trigger

Tab. 7: Status values of oscilloscope

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5.3 Voltage Regulation of the DC Link

Measuring Ranges

For the voltage measurement and regulation of the DC link, there are two voltage-measuring ranges available. These can be switched over by means of bit 3 of the parameter mod-opmode.

If bit 3 is 0, a voltage range of 350V to 400V with a resolution of approx. 0.07V is available. This range recommends itself in connection with other components of the modular transformer system of Flexiva.

If bit 3 is 1, the full voltage range from 0V to 400V is available but only with a resolution of 0.4V. This range recommends itself if the DC link voltage can become smaller than 355V. In this case, attention has to be paid to the fact that the DC link voltage has to be bigger than 1.4 when it is multiplied by the root-mean-square value of the output voltage.

Voltage Regulator

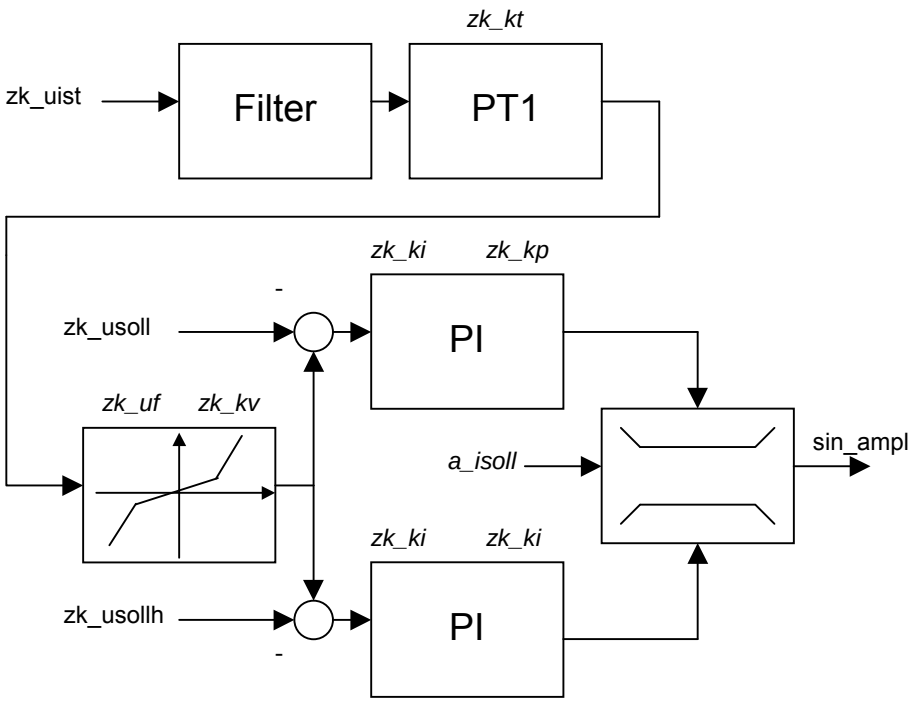

Fig. 5: Block diagram of the DC link voltage control in mains operation

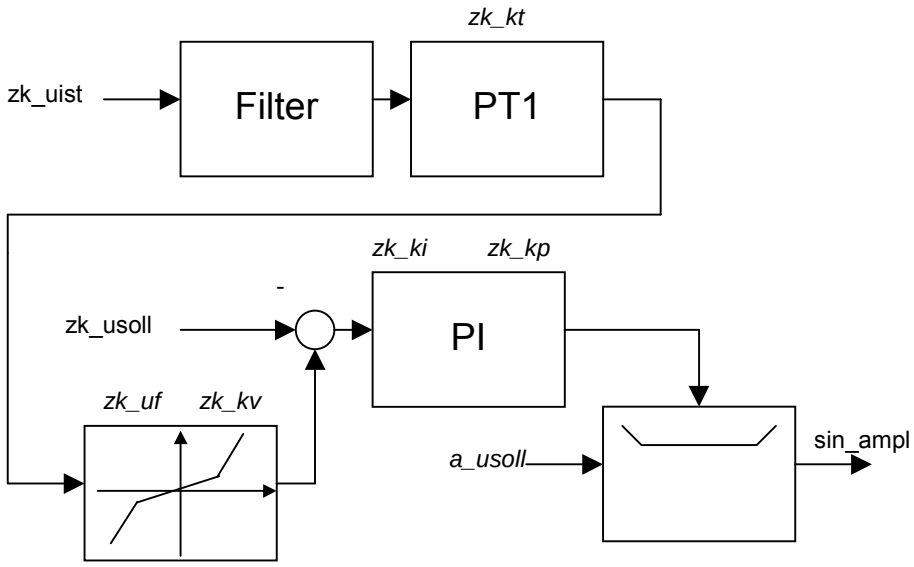

Fig. 6: Block diagram of the DC link voltage control in island operation

The voltage control of the DC link is digitally realized and designed as represented in the figures above. It works as follows: The measured value of the DC link voltage gets first into a comb filter that suppresses the ripple factor that is caused by the fluctuating power. This ripple factor has the double value of the output frequency.

Then, the comparison with the desired value and the PIT1 regulator follows. To suppress additionnally a possibly existing ripple factor of the DC link voltage that would lead to a distortion of the sine-wave form of the output voltage it is possible to define a voltage window (zk_uf). Within this voltage window, the actual-desired value difference is not additionnally amplified. Outside this window, the difference is additionnally amplified with the factor zk_kv. Thanks to that, it is reached that a ripple factor on the DC link voltage acts on the output amplitude only with a low gain in the stationary condition what leads to low distortions. In case of big deviations, e.g. step changes in load, the range of the high gain is reached what leads to a quick smoothing.

In mains operation, two DC link voltage regulators are provided, an upper and a lower one. The upper regulator works when the DC link voltage exceeds its desired value and effects that power is supplied into the mains and/or the power taken from the mains is reduced. The lower regulator works when the DC link voltage remains under its desired value and effects that power is taken from the mains or the power supplied into the mains is reduced.

In the island operation, only one DC link voltage regulator is used. It reduces the output voltage if its desired values is remained under.

Mains Operation

In the mains operation, the voltage control of the DC link can be used to feed excessive power into the mains or to draw lacking power from the mains. In this case, the current is limited to the maximum value of 10Aeff.

If the DC link voltage is between the two desired values of the regulators, the output current is determined by the desired value of the current (a_isoll).

Island Operation

In the island operation, only one DC link voltage regulator is active. In case of a too low DC link voltage, it reduces the output voltage. But if this condition lasts for more than 10s, a shutdown is carried out because of overload.

Falling Characteristic

During the utilization of the DC link regulation in case of modules connected in parallel, tolerances during the measurement of the DC link voltage lead to an uneven load distribution. In order to make the load distribution more even, a falling characteristic of the DC link voltage regulation can be set that simulates an internal resistance. By means of an additional low pass, it is possible to suppress undesired higher-frequency disturbances.

In the mains operation, the output current (in form of the desired value sin_ampl, see Fig. above) is used as control variable. The more power is shifted from a source into the DC link the bigger gets the output current leading to the consequence that the desired value of the DC link voltage is raised. If a module connected in parallel maintains the DC link voltage at a slightly lower value this means that the current is reduced owing to that. Thereby, the load distribution gets evener.

In the island operation, the output power is used as control variable.

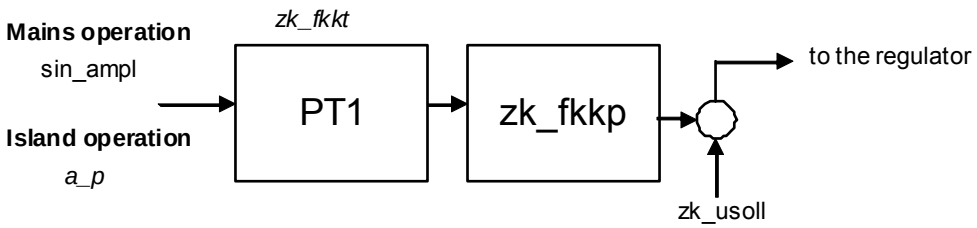

Fig. 7: Block diagram of falling characteristic of DC link voltage control

5.4 Parallel Connection

Mains Operation

In the mains operation, it is possible to connect in parallel as many modules as you like. You only have to pay attention to the fact that N is connected with N and L is connected with L at the output. A connection of L with N can result in a damage of the modules.

You can specify any desired values of current you like to every module.

If the DC link voltage regulation is to be used, the same falling characteristic is to be parameterized at all modules connected in parallel for an even load distribution. Here, it is recommended to set a DC link voltage step of approx. 5V between no-load and full-load.

Island Operation

In the island operation, the modules connected in parallel have to be synchronized. For this purpose, the SYNC-OUT output of the master module has to be connected to the SYNC-IN input of the next module. The SYNC-OUT output of the latter with the SYNC-IN input of the following etc.

The master module is parameterized for normal island operation (bit 5=0). The slave modules are parameterized with bit 5=1 and bit 6=0 in mod_opmode.

The desired values of the output voltage of all modules connected in parallel have to be parameterized identically. The phase relation has also to be parameterized at all modules to the same value (recommended all to 0). For the compensation of circulating currents owing to tolerances, a fine adjustment can be carried out by means of these two parameters after the commissioning. A modification of the desired values of the voltage leads to the flowing of reactive current, a phase displacement mainly to active current.

Furthermore, it is possible to define an internal resistance (parameter a_kri) that leads to an even load distribution. This should be identical at all modules connected in parallel. If the normal PI regulator is selected (bit 0=0 in mod_opmode), this is not absolutely required since this regulator has a steady-state deviation in case of a sine-wave desired value. If the resonant PI regulator is selected (bit 0=1 in mod_opmode), it is a must to parameterize an internal resistance.

First of all, the master module has to be switched on, then the slave modules that check the phase relation before their switching-in. A check of the voltage is not carried out since, when only the master module is in operation at the beginning, this module is possibly overloaded and the voltage generated by it (the master) could be too low.

5.5 Multiphase Operation

Mains Operation

In the mains operation, the modules can be distributed to several phases as you like. It is important that all N-connections of the modules are connected with the N-connection of the mains. An operation at mains without accessible star point is not possible.

If the DC link voltage regulation is to be used, the falling characteristic is to be parameterized at all phases for an even load distribution. Here, it is recommended to set a DC link voltage step of approx. 5V between no-load and full-load.

Island Operation

For the setting-up of a multiphase island network, the modules have to be synchronized. For this purpose, the SYNC-OUT output of the master module has to be connected to the SYNC-IN input of the next module. The SYNC-OUT output of the latter with the SYNC-IN input of the following etc. Of course, it is possible to connect in parallel modules to all these modules to increase the power. These modules have to be synchronized, too. After the successful synchronization, the output SYNC_OUT is always in phase to SYNC_IN.

The master module is parameterized for normal island operation (bit 5=0). The slave modules are parameterized with bit 5=1 and bit 6=1 in mod_opmode as such.

The desired values of the output voltage have to be parameterized identically. The phase relation has to be parameterized at all modules to the desired phase displacement, e.g. 0°,+120° and –120° in case of a three-phase network.

5.6 Typical Cases of Application / Parameterization Examples

To be able to operate the DC/AC module in a certain arrangement, some parameters have to be placed correctly. In the following example configurations, useful instructions are given for the correct parameterization of a DC/AC module in connection with a DC/DC module of the type PM3Kxxx of Flexiva.

Attention

During the initial charging of the DC link it must be unloaded, i.e. there have to be no additional electrical capacities and / or electrical loads connected to the DC link.

5.6.1 DC Link Voltage Modes

In principle, 2 voltage ranges are available with regard to the DC link, the normal DC link voltage range and the full DC link voltage range. In case of the utilization of the DC/AC module with DC/DC modules of the type PM3Kxxx of Flexiva, the utilization of the normal DC link voltage range is recommended for reasons of compatibility, i.e. the DC link range of 350…400V.

For applications requiring another DC link voltage (formed, for example, under the utilization of batteries), the full DC link voltage range, namely the DC link range of 0…400V, should be used. For reasons of efficiency, a DC link voltage of more than 100V is to be recommended in operation. It has to be taken into account that the peak value of the output voltage has to be always smaller than the DC link voltage. Consequently, a maximum output voltage of 70 Veff is possible at a DC link voltage of 100V.

5.6.2 Parameter DC Link Voltage Regulator

The following parameters for the DC link voltage regulator lead in the most cases to an acceptable behaviour. An optimization can be appropriate in certain cases. The oscilloscope function will help to do this.

Command	Parameter	Recommended values
yi	zk_ki	65
yp	zk_kp	350
yt	zk_kt	1000
yf	zk_uf	50
yv	zk_kv	128
yk	zk_fkkp	0 only a single module 100 in parallel operation
yz	zk_fkkt	120 in mains operation 6 in island operation without effect if zk_fkkp=0

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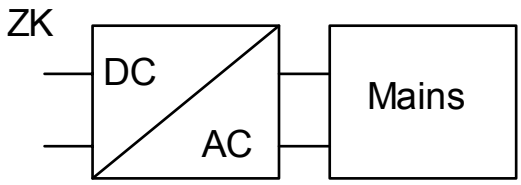
5.6.3 Single Module at the Mains

In example a), the operation of a DC/AC module at the mains is shown. The DC link voltage is supplied from outside. Depending on the voltage range, bit 3 is to be set from mod_opmode.

If the DC link voltage is between zk_usoll and zk_usollh, no DC link voltage regulator is active and the current can be specified as you like by means of the parameter a_isoll (+ → into the mains). Of course, the DC link side source and/or sink is loaded by that what can lead to a change of the DC link voltage. If the DC link voltage reaches the upper and/or lower desired value, the output current is automatically increased and/or reduced by the module.

Depending on bit 4 in mod_opmode, a desired reactive current as phase displacement (a_phase) or as desired value of the reactive current (a_iblind_soll) can be specified.

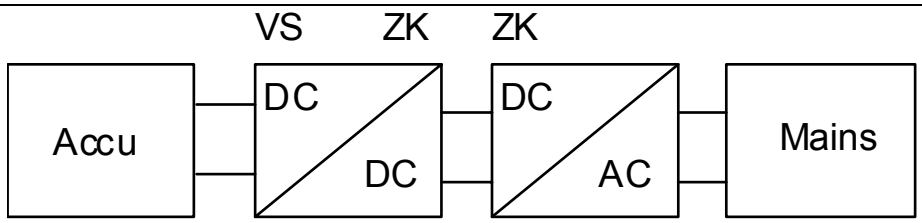
a)		
application	any application	
parameter DC/AC-module at the mains	mod_opmode:	0b00000010=2 / 0b00001010=10 0b00010010=18 / 0b00011010=26
	zk_usoll/zk_usollv:	desired lower dc link voltage, has to be smaller than the minimum dc link voltage in the system
	zk_usollh/zk_usollvh:	desired upper dc link voltage, has to be bigger than the maximum dc link voltage in the system
	a_isoll: (+/-)	desired output current
	a_fsoll:	mains frequency
	a_usoll:	mains voltage
	a_phase/a_iblind_soll	phase / reactive current, dep. on mod_opmode bit 4

5.6.4 Single Module at the Network with DC/DC Module at the DC Link

In connection with a DC/DC converter module of the type PM3Kxxx of Flexiva, the DC/AC module can serve as a network front end for a bidirectional DC source/sink. In connection with an accu, it is possible to set up, for example, a memory unit this way.

In example b), such a memory unit is represented. If the DC/DC module can maintain the DC link voltage at its desired value (this lies between the two desired values of the DC/AC module), the desired value of the current can be set as you like by means of the parameter a_isoll. If the DC/DC converter module gets to a current limit or if the end-of-charge voltage of the memory is reached, the DC module can no longer maintain the DC link voltage at its desired value and the DC link voltage runs upwards or downwards. Here, the DC link voltage regulation of the AC module intervenes and maintains the voltage at zk_usoll or zk_usollh.

The DC/DC converter module only monitors the end-of-charge voltage, i.e. the end-of-discharge voltage has to be monitored externally. The regulator parameters of the DC link voltage regulator are to be set, e.g. with the aid of the oscilloscope function, so that only a low ripple factor gets from the DC link to the VS side of the DC/DC module and thus to the electrical storage (→ reduce gains).

b)		
application	electrical storage	
parameter DC/DC-module at the accu	mod_opmode: vs_imax: vs_imin: zk_usoll: vs_usoll:	0 + desired current limit - desired current limit desired dc link voltage end-of-charge voltage of the storage
parameter DC/AC-module at the mains	mod_opmode: zk_usoll: zk_usollh: a_isoll: a_fsoll: a_usoll: a_phase/a_iblind_soll	0b00000010=2 / 0b00010010=18 desired lower dc link voltage, has to be smaller than the desired dc link voltage of the DC/DC module (min. 5V difference) desired upper dc link voltage, has to be bigger than the desired dc link voltage of the DC/DC module (min. 5V difference) desired output current mains frequency mains voltage phase / reactive current, dep. on mod_opmode bit 4

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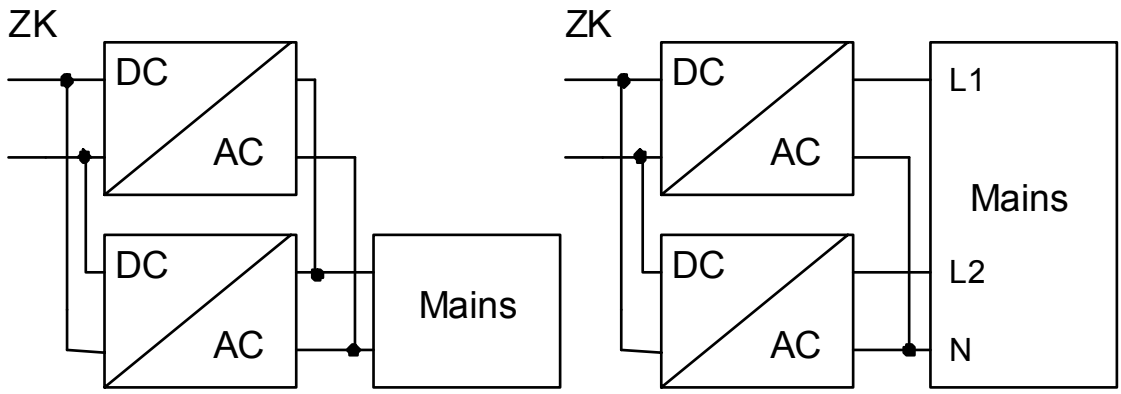
5.6.5 Multiple Modules at the Network

In the mains operation, it is possible to connect several modules in parallel or to distribute them to several phases. Example c) shows such a parallel connection. If the DC link voltage is constant and is not regulated by the AC modules, the current of every AC module can be set individually by means of its a_isoll. If the DC link voltage is to be regulated by the AC modules, it is important to parameterize the same falling characteristic for the DC link voltage regulator by means of the parameters zk_fkkp and zk_fkkt at all modules in order to get an even load distribution.

c)

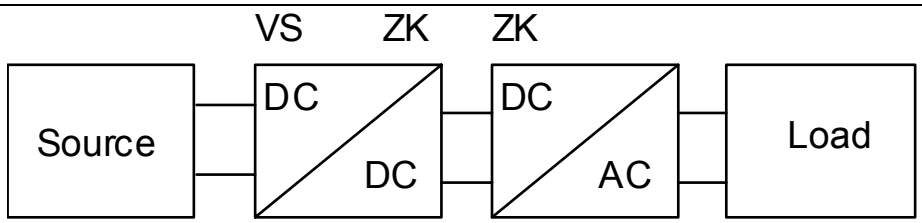


application	any application	
parameter DC/AC-module at the mains	mod_opmode:	0b00000010=2 / 0b00001010=10 0b00010010=18 / 0b00011010=26
	zk_usoll/zk_usollv:	desired lower dc link voltage, has to be smaller than the minimum dc link voltage in the system
	zk_usollh/zk_usollvh:	desired upper dc link voltage, has to be bigger than the maximum dc link voltage in the system
	a_isoll:	desired output current
	a_fsoll:	mains frequency
	a_usoll:	mains voltage
	a_phase/a_iblind_soll	phase / reactive current, dep. on mod_opmode bit 4

5.6.6 Single Module in Island Operation

Example d) shows the application of the AC module in island operation. The DC link voltage regulation of the AC module reduces the output voltage if the DC link voltage remains under the desired value of the DC link of the AC module zk_usoll and/or zk_usollv. This is, for example, the case when the source is no longer able to feed the

load. If this condition lasts longer than 10s, a fault shutdown is carried out because of undervoltage.

d)		
application	any application	
parameter DC/DC-module at the source	mod_opmode: vs_imax: vs_imin: zk_usoll: vs_usoll:	1 + desired current limit 0 desired dc link voltage smaller than the minimum voltage (of the source)
parameter DC/AC-module at the load	mod_opmode: zk_usoll/zk_usollv: a_usoll: a_fsoll:	0b00000000=0 oder 0b00000001=1 0b00001000=8 oder 0b00001001=9 desired dc link voltage, has to be smaller than the minimum dc link voltage in the system desired output voltage desired frequency

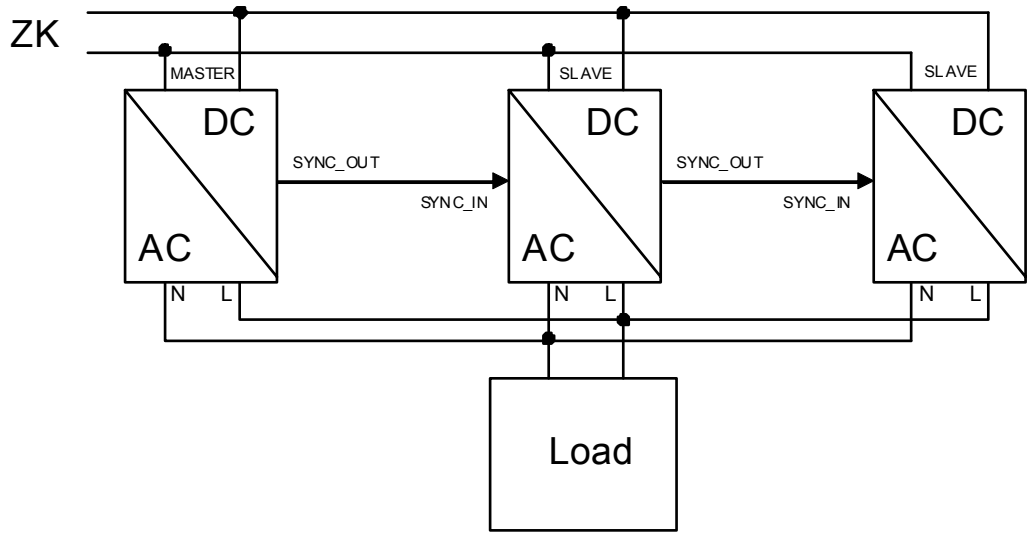
5.6.7 Parallel Operation in Island Operation

In example e), the parallel connection of several modules in island operation is shown. The first module (master) is normally parameterized for the island operation. As far as the slave modules are concerned, bit 5 must be set in mod_opmode in order to enable them to synchronize themselves via the SYNC_IN input.

If bit 0=1 is set in mod_opmode and consequently the resonant PI regulator is activated, an internal resistance has to be parameterized for an even load distribution (parameter a_kri). The desired values of the output voltage of all DC/AC modules involved have to be parameterized identically. The phase relation has to be parameterized to the same value (recommended all to 0) at all modules, too.

During the switching-on, it has to be paid attention to the fact that the master module is switched on first and the slave modules are switched in after a short waiting time.

e)

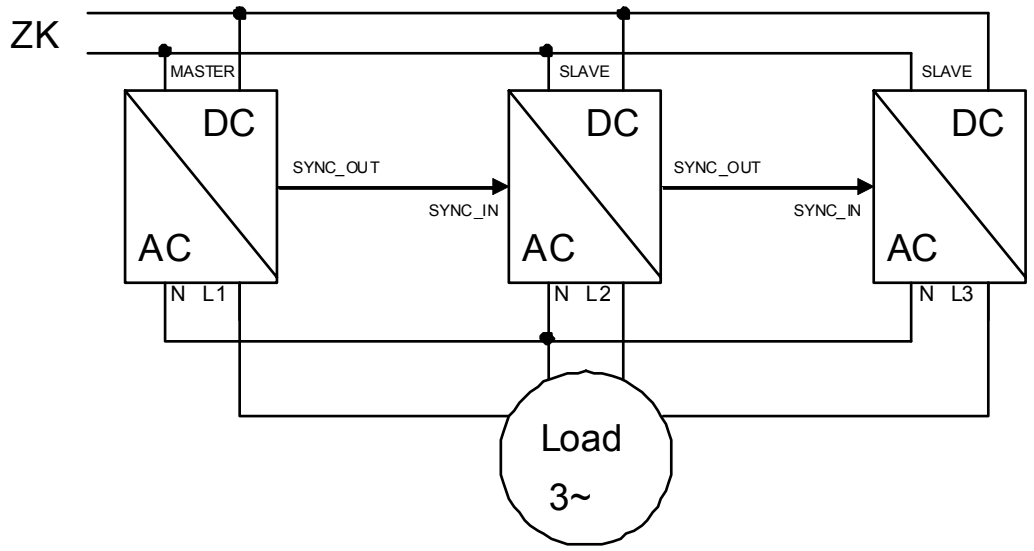


application	any application	
parameter DC/AC-module at the mains	mod_opmode: (master)	0b00000000=0 oder 0b00000001=1 0b00001000=8 oder 0b00001001=9
	mod_opmode: (all slaves)	0b00100000=32 oder 0b00100001=33 0b00101000=40 oder 0b00101001=41
	zk_usoll/zk_usollv:	desired dc link voltage, has to be smaller than the minimum dc link voltage in the system
	a_usoll:	desired output voltage → Must be the same for all modules!
	a_fsoll:	desired frequency
	a_phase:	0
	a_kri:	10 per 1 Ohm, if bit 0 in mod_opmode is set

5.6.8 Multiphase System in Island Operation

For the setting-up of a multiphase island system, the master module has to be configured for the normal island operation. As far as the slave modules are concerned, the bits 5 and 6 must be set in mod_opmode. Bit 5 for the synchronization via SYNC_IN, bit 6 for the multiphase operation, in case of which neither the existence of voltage at the module nor the phase relation of it are checked before the switching-in. The outputs SYNC_OUT are in phase with SYNC_IN each if the synchronization was successful. The phase displacement of the individual modules is fixed by means of the parameter a_phase. Consequently, the angles 0°, +120° and –120° have to be parameterized for a three-phase network.

f)



application	any application	
parameter DC/AC-module at the mains	mod_opmode: (master)	0b00000000=0 oder 0b00000001=1 0b00001000=8 oder 0b00001001=9
	mod_opmode: (all slaves)	0b01100000=96 oder 0b01100001=97 0b01101000=104 oder 0b01101001=105
	zk_usoll/zk_usollv:	desired dc link voltage, has to be smaller than the minimum dc link voltage in the system
	a_usoll:	desired output voltage
	a_fsoll:	desired frequency
	a_phase:	0, +120° -120°

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5.7 Error Handling

Acknowledging of the error, eliminating of the cause, restarting.

6 Programming / Parameterization

6.1 Preliminary Remarks

The DC/AC module offers a convenient software interface. All parameters / commands / measured values can be written and/or read by means of a simple ASCII protocol. All module variables no matter whether they represent a parameter, a measured value or a command are addressable by means of an instruction code consisting of two characters. The first character indicates the respective group membership, e.g. "z“ for the voltage parameters of the DC link and the second character then specifies the concrete variable. A complete list of all instruction codes is part of the present documentation.

The serial interface of the modules serves as (hardware) communication interface. It can, for example, be connected with the RS232 interface of a PC. The following settings are required:

Bits per Second	115200
Data bits	8
Parity	None
Stop bits	1
Flow control	None

Tab. 8: Settings RS232

6.2 The ASCII Protocol used

The transfer of the corresponding commands in the ASCII format is done in a simple scheme. All characters transferred to the module are immediately evaluated by the same and checked with regard to their validity within the respective sequence of commands. This means concretely: If, for example, a plus/minus sign is expected at a certain point of a sequence of commands, the module only accepts the signs plus(+) or minus(-). Valid characters are directly mirrored (exceptions: control characters for the protocol changeover and CR), invalid characters are immediately rejected. With the aid of this procedural method, a complex and extensive protocol (checksums, length specifications etc.) can be avoided and, nevertheless, faulty insertions can be minimized.

From firmware 2.13 on, a protocol with checksum is available (see further chapter).

6.2.1 Read / write without checksum

Basically, you have to distinguish between "Reading" and "Writing" as far as the sequences of instructions to be sent to the module are concerned. If, for example, the value stored in a module variable is only to be read, you have to send the corresponding command code as a sequence followed by Return. If a new value is to be stored in a variable, the corresponding command code, the plus/minus sign of the new value, the new value itself and Return are to be sent.

Read	Write
Command code + CR	Command code + sign + new value + CR

Tab. 9: Command sequences without checksum in general

6.2.2 Read / write with checksum

Basically, you have to distinguish between "Reading" and "Writing" as far as the sequences of instructions to be sent to the module are concerned. If, for example, the value stored in a module variable is only to be read, you have to send the corresponding command code as a sequence followed by Return. If a new value is to be stored in a variable, the corresponding command code, the plus/minus sign of the new value, the new value itself, the checksum and Return are to be sent.

Read	Write
Command code + Σ + CR	Command code + sign + new value + Σ + CR

Tab. 10: Command sequences with checksum in general

The following table lists all possible command codes for the communication with the module and they are arranged in groups. At the same time, the names of the respective module variables as well as the place of storing and the parameterability are shown.

Group	Description	1. Command Character	2. Command Character	parame-trizable	stored in EEPROM	Parameter
DC link	voltage, normal range: lower regulator, desired value	z	u	x+		zk_usoll
(DC link side)	voltage, normal range: lower regulator, desired initial value in EEPROM	z	v	x	x	zk_usoll_f
	voltage, normal range: upper regulator, desired value	z	s	x+		zk_usollh
	voltage, normal range: upper regulator, desired initial value in EEPROM	z	t	x	x	zk_usollh_f
	voltage, full range: lower regulator, desired value	z	q	x+		zk_usollv
	voltage, full range: lower regulator, desired initial value in EEPROM	z	r	x	x	zk_usollv_f
	voltage, full range: upper regulator, desired value	z	o	x+		zk_usollvh
	voltage, full range: upper regulator, desired initial value in EEPROM	z	p	x	x	zk_usollvh_f
	voltage, normal range: actual value	z	a			zk_uist
	voltage, full range: actual value	z	b			zk_uistv
	voltage: upper limit (not used)	z	m	x	x	zk_umax_g
	voltage: lower limit (not used)	z	n	x	x	zk_umin_g
	regulator: I-component	y	i	x	x	zk_ki
	regulator: P-component	y	p	x	x	zk_kp
	regulator: time constant	y	t	x	x	zk_kt
	voltage window for the gain increase	y	f	x	x	zk_uf
	gain increase outside the voltage window	y	v	x	x	zk_kv
	falling characteristic ("internal resistance"): gain	y	k	x	x	zk_fkkp
	falling characteristic ("internal resistance"): filter time constant	y	z	x	x	zk_fkkt
Output	frequency: desired value	w	f	x		a_fsoll
(AC side, (component side)	frequency: desired initial value in EEPROM	w	g	x	x	a_fsoll_f
	frequency: actual value	w	h			a_fist
	phase angle: desired value	w	p	x		a_phase
	phase angle: desired initial value in EEPROM	w	q	x	x	a_phase_f
	current: desired value	w	i	x+		a_isoll
	current: desired initial value in EEPROM	w	j	x	x	a_isoll_f
	reactive current: desired value	w	k	x+		a_iblind_soll
	reactive current: desired initial value in EEPROM	w	l	x	x	a_iblind_soll_f
	voltage: desired value	w	u	x+		a_usoll
	voltage: desired initial value in EEPROM	w	v	x	x	a_usoll_f
	internal resistance: desired value	w	z	x	x	a_kri
	voltage: r.m.s. value of the output, measured value	v	u			a_ueff
	voltage: r.m.s. value of the mains, measured value	v	w			n_ueff
	current: r.m.s. value, measured value	v	i			a_ieff
	power: actual value	v	p			a_p
	voltage: DC component	v	d			a_udc
	current: actual amplitude value (mains operation)	v	j			a_iampl
	voltage: actual amplitude value (island operation)	v	v			a_uampl
Temperatures	heat sink	t	k			t_kk
Info	module state	i	s			mod_state
	module operating mode	i	m	x	x	mod_opmode
	module type	i	t			
	module firmware	i	f			
	module serial number	i	n		x	
	module date of manufacture	i	d		x	
Commands	module on / off	c	e	x+		mod_on
	acknowledge an error	c	q	x		err_quit
	communication mode	c	c			com_mode
Oscilloscope	channel	o	k	x+		osz_ch
	frequency divider	o	f	x+		osz_ft
	trigger value	o	t	x+		osz_tr
	trigger channel	o	c	x+		osz_tch
	storage mode	o	m	x+		osz_m
	oscilloscope on / off	o	e	x+		osz_on
	read data (only the channel osz_ch)	o	r			
	read data (all channels)	o	s			
x+ also parametrizable, if the module is switched on (mod_on=1)						

Tab. 11: Complete table of the command codes

6.2.3 ASCII-long / ASCII-short

On the part of the module answer, two protocol variants are possible: "long" and "short" ASCII protocol. ASCII-long is particularly suited for the manual entry of instructions, e.g. by using a terminal program such as "HyperTerminal" from Windows. When this protocol is set, the module sends any information and (error) messages in clear text and sees to a distinct representation in the terminal program by means of the transfer of CR and NL control characters at corresponding points.

On the other hand, the protocol ASCII-short should be used when the instruction is to be handed over from another software such as, for example, from the software "ModuleConfigSuite" of Flexiva. If this protocol is set, any information and (error) messages in clear text are suppressed. In case of an error, only error codes are transferred.

	ASCII-long	**ASCII-short**
without error	- command code + CR + NL - sign + readout value + CR + NL - „OK“ + CR + NL + NL	- command code + CR - sign + readout value + CR
with error	- command code + CR + NL - error code + CR + NL - error text + CR + NL + NL	- command code + CR - error code + CR

Tab. 12: Module answer for the reading of a parameter / value

	ASCII-long	**ASCII-short**
without error	- command code + sign + new value + CR + NL - sign + read back value + CR + NL - „OK“ + CR + NL + NL	- command code + sign + new value + CR - sign + read back value + CR
with error	- command code + sign + new value + CR + NL - error code + CR + NL - error text + CR + NL + NL	- command code + sign + new value + CR - error code + CR

Tab. 13: Module answer for the writing of a parameter / value

6.2.4 ASCII-short with checksum

Starting with firmware 2.13 a communication protocol with checksum is available. This is based on the existing protocol "ASCII-short". However, a 1-byte checksum is used now instead of resending each character received for error checking. This checksum is transmitted in each case as the last character before the CR (dec. 13) in both directions of communication.

The checksum is calculated as the sum of all transmitted bytes modulo 256. If the result is randomly 13, it is replaced by 14 in order to avoid collisions with the CR (dec. 13) as an input terminator.

	ASCII-short with checksum
without error	- command code + Σ + CR - sign + read back value + Σ + CR
with error	- command code + Σ + CR - error code + Σ + CR

Tab. 14: Module answer during reading of a parameter / value

	ASCII-short with checksum
without error	- command code + sign + new value + Σ + CR - sign + read back value + Σ + CR
with error	- command + sign + new value + Σ + CR - error code + Σ + CR

Tab. 15: Module answer during writing of a parameter / value

When reading the data from the oscilloscope no checksum is transmitted. Here, the data transmission is as in the ASCII-short protocol.

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6.2.5 Switching between the protocols

The changeover between the protocol variants is executed by putting a command character in front of the respective first sequence of commands. This command character can also be sent separately. The respective protocol setting is preserved until the next protocol changeover and/or to the next restart (supply voltage gone) or reset of the module. As a standard setting, ASCII-short is set.

Protocol-option	Control character to the module
ASCII-short	$
ASCII-long	%
ASCII-short with checksum	&

Tab. 16: Protocol changeover

6.2.6 Concrete example

To explain the above-mentioned paragraphs, the sequences of instructions to be transferred to the module and the corresponding answers of the module are listed in the following at a concrete example. The case without errors is treated.
The module variable zk_umin_g is to be read-out and a new value is to be stored in it. The corresponding code is "zn", the old value in the variable is "+3500" and the new value is "+3600". This results for the two ASCII modes in the following communication with the module:

6.2.6.1 ASCII-long

To the Module																							
ASCII	%	z	n	CR																			
HEX	25	7A	6E	OD																			
From the Module																							
ASCII		z	n	CR	NL	+	3	5	0	0	CR	NL	O	K	CR	NL	NL						
HEX		7A	6E	0D	0A	2B	33	35	30	30	0D	0A	4F	4B	0D	0A	0A						

Tab. 17: Reading ASCII-long

To the Module																					
ASCII	%	z	n	+	3	6	0	0	CR												
HEX	25	7A	6E	2B	33	36	30	30	0D												
From the Module																					
ASCII		z	n	+	3	6	0	0	CR	NL	+	3	6	0	0	CR	NL	O	K	CR	NL
HEX		7A	6E	2B	33	36	30	30	0D	0A	2B	33	36	30	30	0D	0A	4F	4B	0D	0A

Tab. 18: Writing ASCII-long

6.2.6.2 ASCII-short

To the Module																							
ASCII	$	z	n	CR																			
HEX	24	7A	6E	OD																			
From the Module																							
ASCII		z	n	CR	+	3	5	0	0	CR													
HEX		7A	6E	0D	2B	33	35	30	30	0D													

Tab. 19: Reading ASCII-short

To the Module																							
ASCII	$	z	n	+	3	6	0	0	CR														
HEX	24	7A	6E	2B	33	36	30	30	0D														
From the Module																							
ASCII		z	n	+	3	6	0	0	CR	+	3	6	0	0	CR								
HEX		7A	6E	2B	33	36	30	30	0D	2B	33	36	30	30	0D								

Tab. 20: Writing ASCII-short

6.2.6.3 ASCII-short with checksum

To the Module																							
ASCII	&	z	n	Σ	CR																		
HEX	26	7A	6E	E8	0D																		
From the module																							
ASCII						+	3	5	0	0	Σ	CR											
HEX						2B	33	35	30	30	F3	0D											

Tab. 21: Reading ASCII-short with checksum

To the Module																							
ASCII	&	z	n	+	3	6	0	0	Σ	CR													
HEX	26	7A	6E	2B	33	36	30	30	DC	0D													
From the Module																							
ASCII											+	3	6	0	0	Σ	CR						
HEX											2B	33	36	30	30	F4	0D						

Tab. 22: Writing ASCII-short with checksum

For computing the checksum the gray values are added. The residue left in the Division by 256 is the checksum. If this value is 13, it is replaced with 14.

```
char checksum;
...
checksum = 0;
   for (i = 0; i < idx; i++) checksum = checksum + buf[i];
   if (checksum == 13) checksum = 14;
...
```

Tab. 23: Example for computing the checksum in C

6.2.7 Error messages during the communication

All sequences arriving in the module are immediately checked and processed. The following errors can occur during the reading / writing and these errors concern exclusively the parameterizing process and are not to be confused with the errors that may arise during the operation of the module and are coded in the status variable mod_state (Tab. 5):

Error code	Meaning in clear text
E0	Reserve
E1	Reserve
E2	Invalid module command
E3	Value is out of range
E4	Value is read only
E5	Device must be switched off
E6	Not used
E7	Not used
E8	Min-value must be smaller than the max-value
E9	Checksum error

Tab. 24: Error messages

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6.3 Communication by Means of a Terminal Software

Because of the utilization of an ASCII protocol for the communication interface, a communication with the module is possible by means if any terminal software you like. As an example, HyperTerminal is mentioned here that is part of the older (below windows7) windows versions (see Fig. 8). Of course, every other software can be also applied (Freeware, self-developed software) by means of which a bidirectional serial communication is possible. For the utilization of terminal software, the protocol setting ASCII-long is recommended.

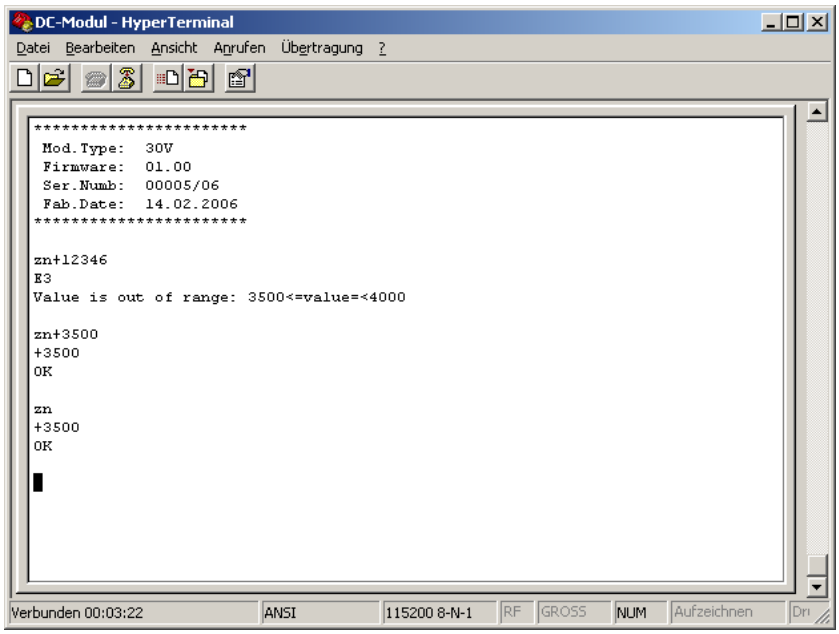

Fig. 8: Module parameterization by means of a terminal software

6.4 Communication by Means of ModuleConfigSuite

Another and much more convenient possibility is the utilization of the Windows software "ModuleConfigSuite" from the company Flexiva that is contained in the scope of delivery of the inverter module as a standard component. This software permits a convenient communication and a closed access (parameterizing / monitoring / storing) to all variables (parameters / commands / measured values) of every single module. Furthermore, it is possible to communicate simultaneously with up to 4 modules. The ModuleConfigSuite uses the protocol setting ASCII-short

7 The Parameterizing Software "ModuleConfigSuite"

7.1 Preliminary Remarks

A Windows-software for the PC is supplied along with the module. It is intended for the convenient parameterization and visualization of all parameters / commands / measured values as well as for the recording of selected data on the PC. In the following, details concerning the function and operation of this software are explained.

System requirements

Hardware:
- customary PC of medium performance and RS232 interface

Operating system:
- MS Windows (from Windows XP SP2 onwards)

7.2 Installation

The software is installed like any other conventional Windows software:

1. Insert the data carrier.
2. Start the installation by means of starting the file **setup.exe**.
3. Follow the instructions given by the installation program (path entry etc.).
   a. Installation step backwards by means of a click onto **Back**
   b. Installation step forwards by means of a click onto **Next**
   c. Stop the installation by means of a click onto **Cancel**
4. Terminate the installation by means of a click onto **Finish**

7.3 Deinstallation

If the software is to be removed from the PC, you proceed as follows:

1. Open the **Start menu** of Windows.
2. Select **System control**.
3. In the system control panel click onto the symbol **Software**.
   A list of the available programs is displayed.
4. Select from the list the symbol for **ModuleConfigSuite**.
5. Click onto **Remove**. The software is de-installed now.

7.4 Software description

7.4.1 Overview

After the start of the software and the successful establishing of a connection to one or several modules (click on "Connect!" in the menu line), the following window is displayed in which a division into three parts that is into a menu line, a button bar directly under the menu line and the remaining display area can be recognized. Only those modules are displayed with which a connection is to be established (see paragraph "Selection and Assignment of the Interfaces“) and a connection was successfully established.

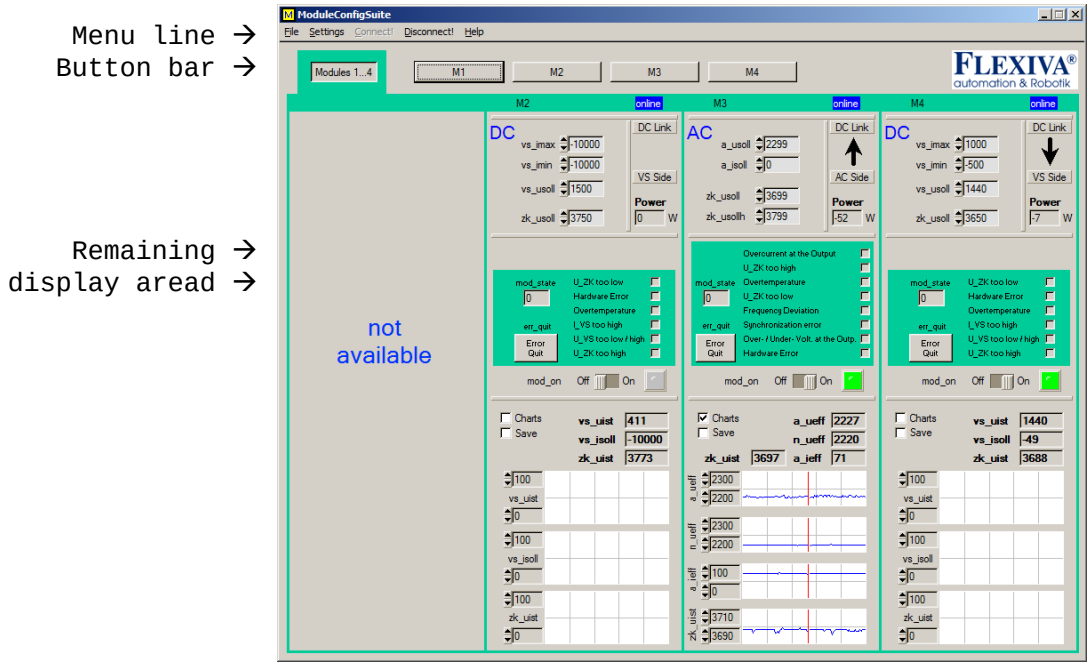

Fig. 9: Basic structure of the software

7.4.2 Single-Mode / Multi-Mode

On principle, the software distinguishes between two modes, the so-called "Single"-mode for the communication with only one single module and the so-called "Multi"-mode for the simultaneous communication with up to 4 modules. In the Single-mode, the access to all parameters of the respective module is possible while in the Multi-mode, the access only to selected parameters of the respective module is possible. In the Single-mode, the digital nameplate and temperature values of the respective module are read-out and visualized additionally. Furthermore, an oscilloscope function and a selection aid for the fixing of the mode of operation (mod_opmode) are available. The changeover between the modes is executed by means of the buttons in the upper window area. After the start of the software, the Multi-mode is automatically set.

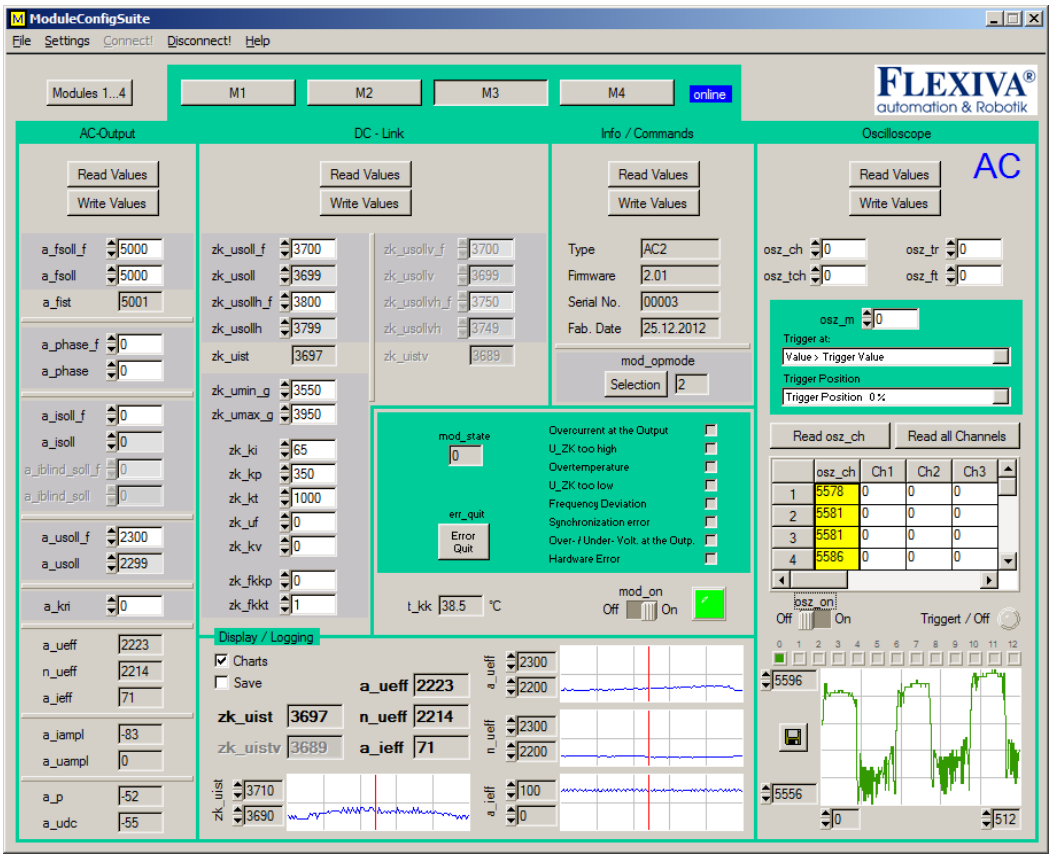

Fig. 10: Single-mode / module 3

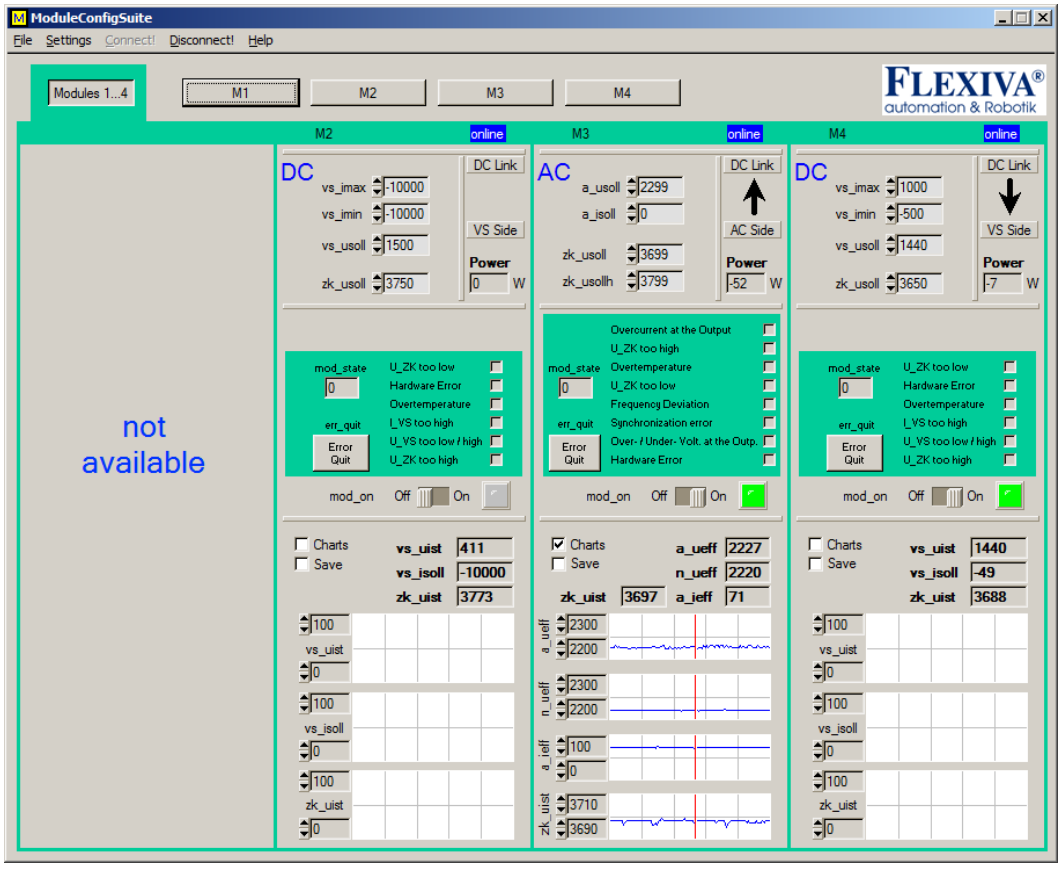

Fig. 11: Multi-mode

7.4.3 Groupings by Means of Colours / Backgrounds

Owing to the great number of information to be represented at the same time and the diversity of the entries to be processed, the application of different colors for the logical grouping turned out to be advantageous. The legend with the explanation of the colors can be called after the selection of the menu item "Help → Color Codes".

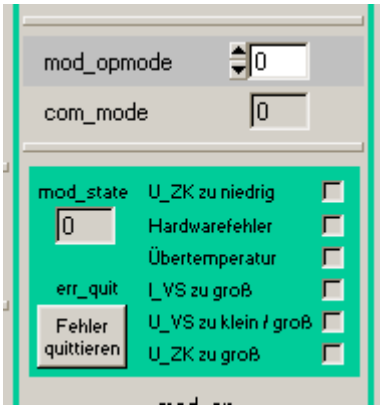

Fig. 12: Example for groupings

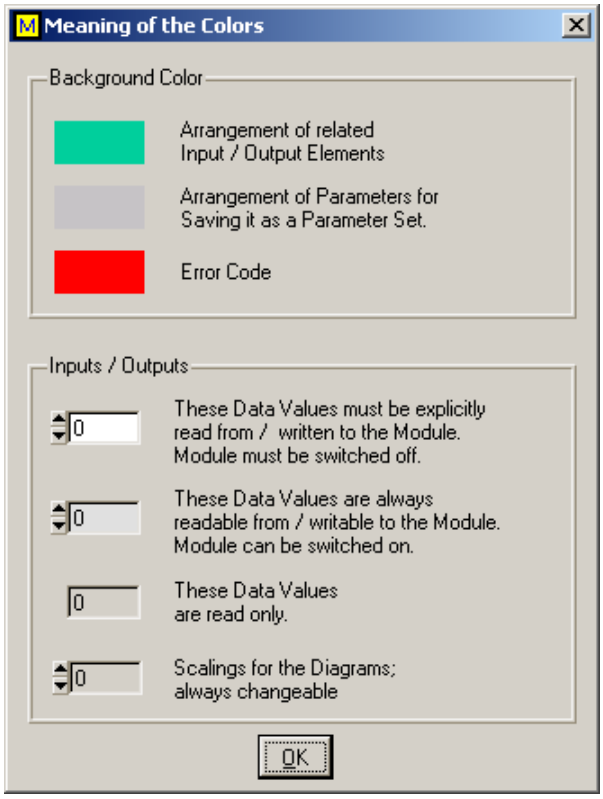
Meaning of the Colors
Background Color
Arrangement of related Input / Output Elements
Arrangement of Parameters for Saving it as a Parameter Set.
Error Code
Inputs / Outputs
These Data Values must be explicitly read from / written to the Module. Module must be switched off.
These Data Values are always readable from / writable to the Module. Module can be switched on.
These Data Values are read only.
Scalings for the Diagrams; always changeable
OK

Fig. 13 : Color legend

7.4.4 Meaning of the Error Codes

All data that are transferred (for example, by a click onto one of the buttons "Write Values" in the single-mode) to the module, are immediately checked there with regard to their validity. In case of an error, the corresponding error code is entered in a red field directly next to the respective display / entry element. A table with the meaning of the error codes can be retrieved by selection of the menu item „Help → Error Codes“.

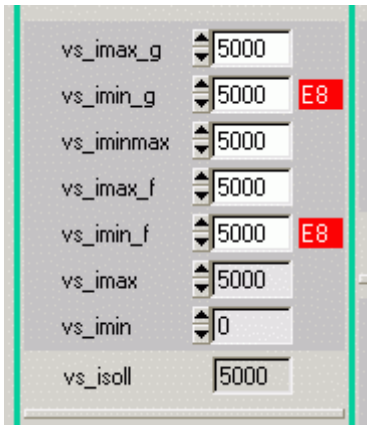

Fig. 14: Example of error codes

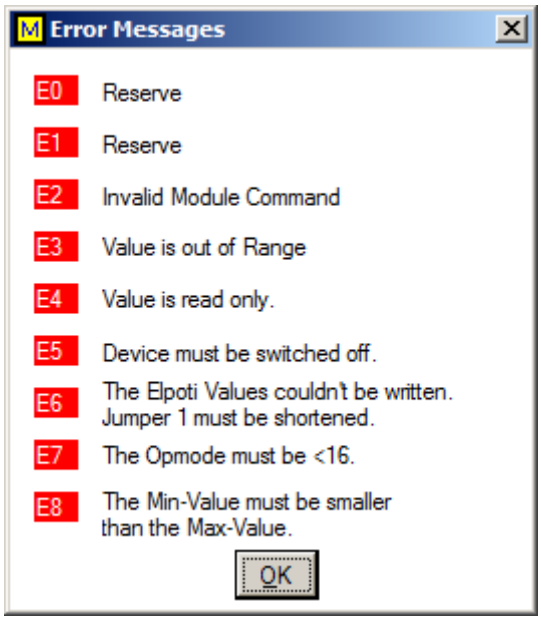
Error Messages
E0 Reserve
E1 Reserve
E2 Invalid Module Command
E3 Value is out of Range
E4 Value is read only.
E5 Device must be switched off.
E6 The Elpoti Values couldn't be written. Jumper 1 must be shortened.
E7 The Opmode must be <16.
E8 The Min-Value must be smaller than the Max-Value.
OK

Fig. 15: Meaning of the error codes

7.4.5 Selection and Assignment of the Interfaces

The selection of the interfaces and their assignment to the modules is carried out by the selection of the menu item "Settings → Connection". Depending on the type of the module carrier, there are various possibilities available. In case of the module carrier of the type 1, the communication is executed by means of 4 separate RS232 interfaces (one for every module). The module carrier of the type 2 needs only one RS232 for the communication with all modules (is multiplexed in the module carrier).

In addition to the assignment of the interfaces, you also have to select explicitly by marking a checkbox in the configuration dialogue whether communication with the respective module is intended. This offers the possibility to include the individual modules in the communication or not.

During the selection and assignment of the rs232 interfaces, tests are carried through concerning the existence in the PC and/or availability.

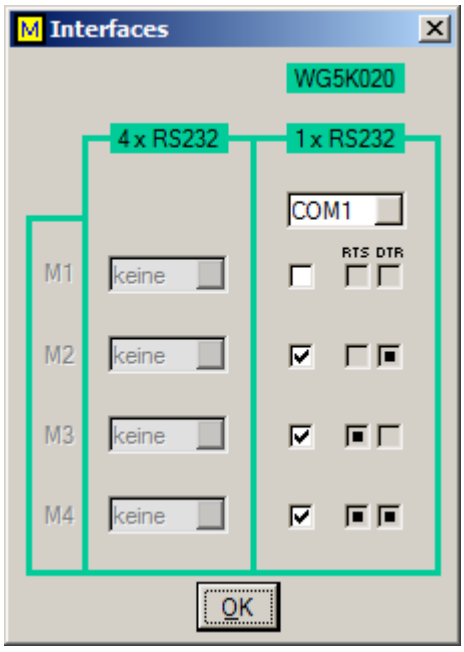

Fig. 16: Assignment of the interface

Attention: Only a test of the chosen interfaces and their assignment to the modules is made. The data connection to the modules is only established after the selection of the menu item "Connect!".

7.4.6 Connecting / Disconnecting

By the selection of the menu item "Connect!" it is possible to establish a data connection to the corresponding module (single-mode) and/or to the modules multi-mode). In the single-mode, all data are read-out once completely from the chosen module after the successful establishing of the connection and entered into the respective fields of the screen mask. In the multi-mode, only the relevant data are read-out after the successful establishing of the connection and entered into the respective fields of the screen mask. A selection of the menu item "Disconnect!" cut(s)-off the connection(s).

Fig. 17: Information in case of the cutting-off of the connection

The connection is permanently monitored both during the establishing of the connection and during the existing connection. If the establishing of the connection fails and/or the connection is cut-off a corresponding hint appears.

7.4.7 Storing / Loading of Parameter Sets

In the single-mode, it is possible to store parameter sets on the PC and/or to load parameter sets that are stored on the PC. After the calling of the menu items "File → Load Parameter Set" and/or "File → Save Parameter Set", the corresponding dialogues are called for the loading and storing of files. The parameter files have got a special format that can only be read and write by the ModuleConfigSuite.

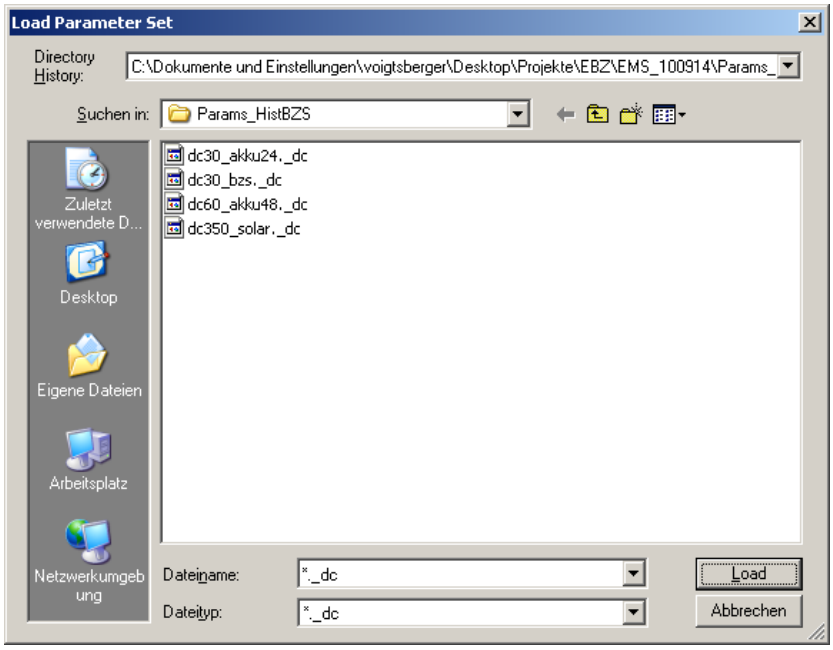

Fig. 18: Dialogue for the loading of parameter files

When such a file is loaded from the PC, all parameters are immediately entered into the corresponding fields. In the reverse case, only the corresponding fields are read-out for the storing of the parameters in such a file. Only such fields with the respective colored background are taken into account.

7.4.8 Reading-Out / Parameterization

All relevant data are automatically read-out from the module and/or the modules during the changeover between the two main modes single-mode and multi-mode (buttons: "Modules 1…4" and "M1" … "M4") or during the establishing of the connection ("Connect!"). In the single-mode, all data are read-out from the selected module and entered into the corresponding fields of the screen mask, in the multi-mode only the relevant ones. The requirement is in both modes an existing data

connection to the respective module and/or to the respective modules.
In addition to that, it is possible in the single-mode to explicitly initiate the reading-out of the data from the module and/or the storing of data in the module by means of a click onto one of the buttons "Read Values" or "Write Values". Only the data of the respective column (e.g. "DC link") are taken into account during this.

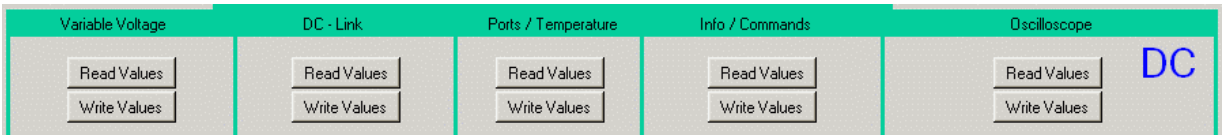

Fig. 19: Buttons for the reading-out / parameterization in the single-mode

Both in the single-mode and in the multi-mode, some data are immediately transferred after their entry / modification (see color codes). These are in particular the parameters: a_isoll, a_usoll, zk_usoll (zk_usollv) and zk_usollh (zk_usollvh).

7.4.9 Data Visualization / Recording

In the single-mode as well as in the multi-mode, in case of an existing connection, the parameters a_ueff, n_ueff, a_ieff, zk_uist (zk_uistv) and mod_state are permanently read-out and visualized with a transfer rate of approx. 10 Hz when the connection exists. If the check boxes "Charts" and "Save" are marked, in addition to that, the parameters a_ueff, n_ueff, a_ieff, zk_uist (zk_uistv) are simultaneously visualized in diagrams and data are stored (data-logging) in the ASCII format.

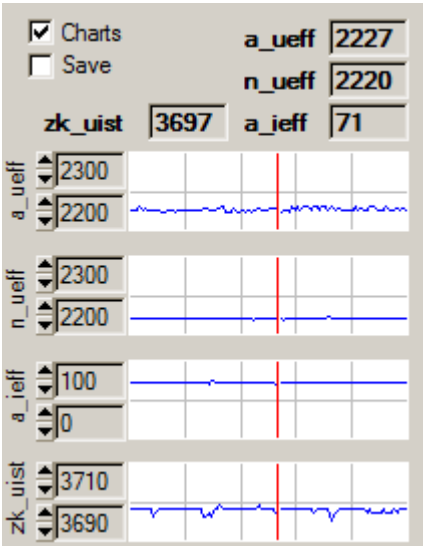

Fig. 20: Dialogue field storing / visualizing

zk_uist	a_ieff	a_ueff	n_ueff
3698	69	2231	2218
3698	69	2231	2218
3697	69	2231	2218
3698	69	2231	2218
3697	69	2231	2218
3697	69	2231	2218
3697	69	2231	2218
3697	69	2231	2218
3697	69	2229	2218
3697	69	2231	2218
3697	69	2231	2218
3697	69	2231	2218
3697	69	2231	2220
3696	69	2231	2218
3696	69	2231	2218

Fig. 21: Recorded ASCII data

During every new establishing of a connection by means of a click onto "Connect!" and a marked "Save", a new data file (a separate one for every module) in the ASCII format with the file extension *.asc is automatically generated in the working directory of the ModuleConfigSuite. For this purpose, it does not matter whether you are in the single-mode or in the multi-mode. The file names of the generated files are composed of the module code as well as date and time of the beginning of the recording. Consequently, the file name “M3_110406_114231.asc“ designates a data recording of the module 3 that started on 11th April 2006 at 11:42:31 a.m.
For safety reasons, the data are stored only in the corresponding mode (single-/ multi-) respectively in the single-mode only for the module just selected. If, for example, the storing is marked for all 4 modules in the multi-mode, only a storing of the data in the file of the corresponding chosen module is carried out in the single-mode and no (background) storing of the data of all 4 modules is executed. Single-mode and multi-mode store to the same data file of the respective module.

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7.4.10 Selecting of the Mode of Operation

In the Single-mode, it is possible to select the required mode of operation in a simple way. By means of simple dialogue field (invocation by means of button "selection" in the field "mod_opmode“), all bits of the parameter mod_opmode and their dependencies from each other are visualized and the corresponding decimal value of the parameter mod_opmode is calculated. After clicking "Apply", this value is applied and stored in the module.

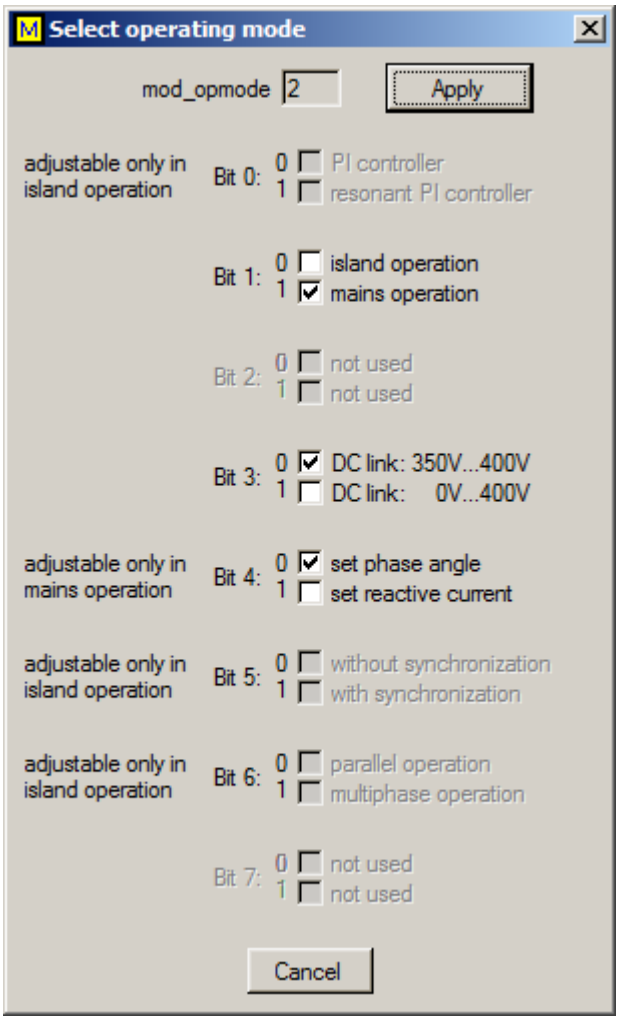

Fig. 22: Dialogue for the selection of the mode of operation

8 Maintenance service and repairs by the customer service

According to the general terms and conditions of sale and delivery, WARRANTY is furnished for the device provided by the manufacturer. If malfunctions or damages occur at the device during the warranty period warranty is given for according to the terms and conditions of warranty, the manufacturer shall execute the repair or the replacement of defective components after a prior examination.

The manufacturer shall be responsible for the device in its original configuration.

Only the manufacturer shall be authorized to carry out all and any interventions that concern the device, the structure, the software, or the operating cycle of the device or these interventions exclusively require the express prior consent of the manufacturer.

Attention

The environmental conditions agreed in the contract must be met.

The manufacturer shall not be liable for any damages owing to the improper or false utilization of the device as well owing to damages arising from interventions to the device that are not expressly required in the present manual.

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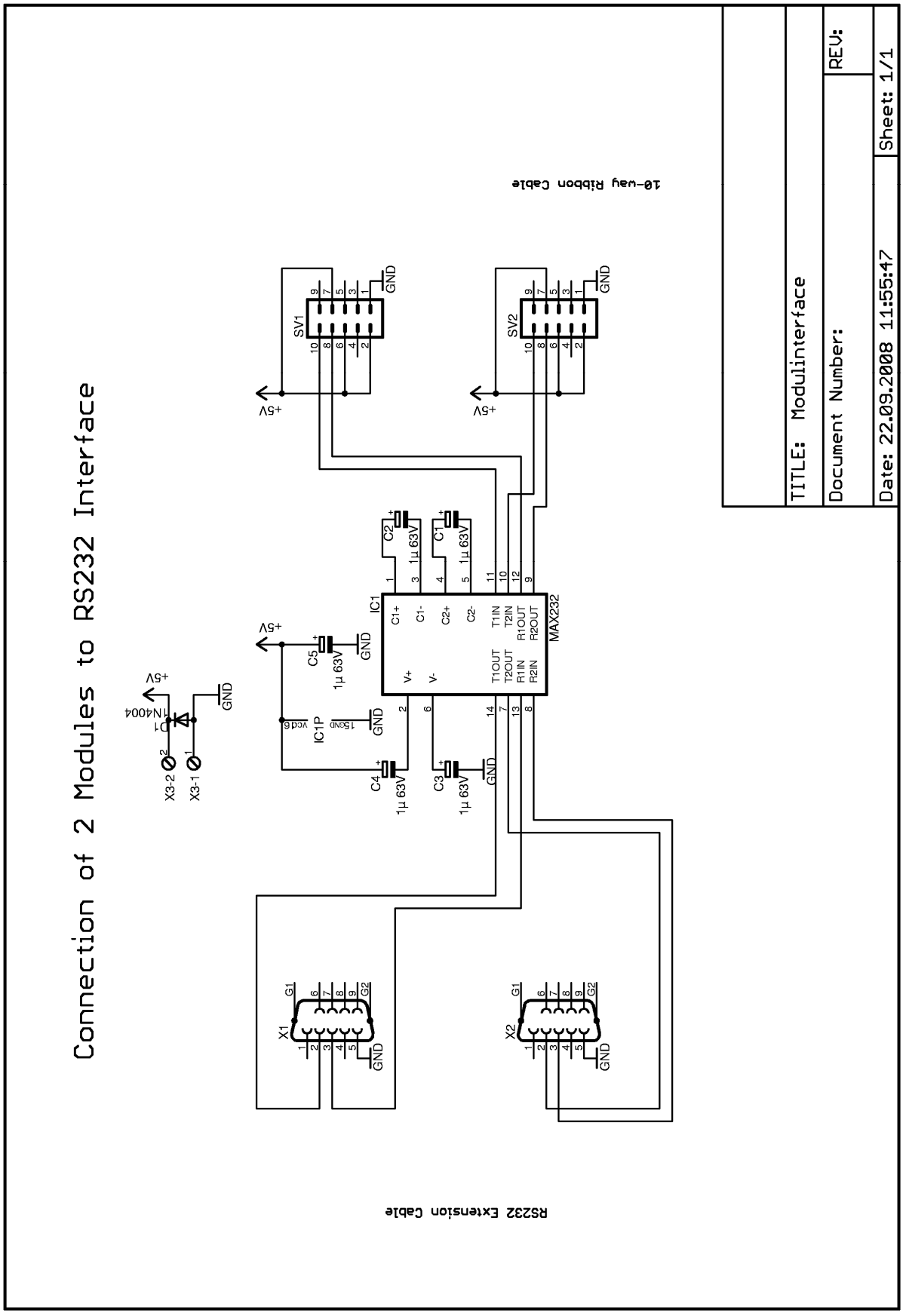
9 Appendix


Connection of 2 Modules to RS232 Interface
10-way Ribbon Cable
RS232 Extension Cable
TITLE: Modulinterface
Document Number:
REV:
Date: 22.09.2008 11:55:47
Sheet: 1/1
SV1
SV2
X1
X2
X3-1
X3-2
IC1
IC1P
MAX232
C1
C2
C3
C4
C5
D1
1N4004
+5V
GND
1µ 63V

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